FINAL REPORT

ON

PHASE II OF THE BROADBAND ANTENNA STUDY PROGRAM

FOR THE PERIOD OCTOBER 21, 1962 TO MARCH 21, 1963

COMPRISING

A) A report on the continuation of the "State-of-the-Art" survey in accordance with Section AI of Contract NOm 72423.

B) A report on scale model evaluation in accordance with Section AII and III of Contract NOm 72423.

Prepared for:

HEADQUARTERS, U. S. MARINE CORPS
Navy Annex, Washington 25, D. C.
Contract NOm 72423

May 7, 1963

KEARFOTT DIVISION
GENERAL PRECISION, INC.
LITTLE FALLS, NEW JERSEY

ABSTRACT

The work outlined in this report has been conducted in accordance with the requirements of Contract NOm 72423 for the United States Marine Corps. It covers those investigations carried on in the interim period since the submission of the interim study report (Ref. 61). This program has both an immediate and long range purpose. Its immediate purpose is to determine an antenna design which will provide the Marine Corps with a broadband antenna over the range 6-30 mc considerably reduced in size from those presently available and capable of simple and rapid field installation. Its long range purpose is the continuation of these investigations in an effort to further develop a size reduced antenna over the extended range of 2-100 mc.

Two new models of the Scimitar, several UHF models and a VHF model of the Sinuous Log Periodic were tested and evaluated. It is shown that of all the scale model evaluations conducted under Contract NOm 72423, including the Log Conical Spiral and the first Scimitar model, which are discussed in the preceding interim study report (Ref. 61), Scimitar No. 2 model will provide the greatest size reduction and ease of installation.

A proposed mechanical design and installation instructions for a full scale engineering model of Scimitar No. 2,designed to operate over the range 6-42 mc, is included.

Within the "state-of-the-art" survey several new developments are discussed. These include a discussion of a Fast Wave Antenna investigation, preliminary tests on a multi-turn loop tunable configuration developed at Kearfott, and the Hula Hoop (DDRR) antenna. Mention is also made of a new lightweight transportable Log-Periodic Antenna developed by Granger Associates and a new broadband multicoupler which will operate over the range 2-30 mc.

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1.0 INTRODUCTION

This report covers the work conducted, within the past five month interval, on the Broadband Antenna Study Program under Contract NOm 72423.

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This report consists of two parts, namely:

1. Scale model evaluation of the Sinuous Log Periodic Antenna and two new models of the Scimitar Antenna. Investigations conducted on the first model of the Scimitar Antenna and the Log Conical Spiral were reported in the preceding interim study report.

2. A supplemental review of advances in the "state-of-the-art" since the writing of the preceding interim study report.

2.0 "STATE-OF-THE-ART" SURVEY

A continuing search of the literature and contacts with organizations currently associated with research investigations in this field have revealed some new developments which are briefly described in the following paragraphs:

2.1 Fast Wave Antennas

In the preceding interim study report (Ref. 61) it was noted that Professor Mayes of the University of Illinois suggested that a fast wave structure, consisting of a long wire antenna with many series capacitors, might serve as a small portable antenna. Laboratory feasibility tests which were indicated at that time were not initiated in view of the report (Ref. 10), since discovered, covering a contemporary investigation into this phenomenon. Although the specific structure under investigation consisted of a parallel plate balanced line several wavelengths long and inductively shunt loaded, the characteristics would be similar for the series capacitance loading case. As evidenced by this report, the fast wave structure investigated does not appear to lend itself to the ultimate goal of this program. Although radiation is maintained over a fairly wide band of frequencies, the radical variations in directivity prohibit its application to this program. These radical variations in directivity are clearly exemplified by the radiation patterns shown over a 2:1 bandwidth in Figures 2-1 and 2-2.

2.2 Multi-Turn Loop Antenna

The theory of the Multi-Turn Loop Antenna was developed by Dr. Julius Herman. Formerly of Diamond Ordnance Fuze Lab and Republic Aviation Company, Dr. Herman is now a member of Kearfott Division's Research Staff.

To supplement the theoretical analysis discussed in the previous report (Ref. 61), a 33 inch diameter, 6 turn antenna has been constructed and tested in comparison with a 15 foot whip antenna tuned to 2.8 megacycles under the auspices of the Kearfott Research Center. The test loop antenna is shown in Figure 2-3. While tests were made only for radiation efficiency, the results are indicative of the potential application of the Multi-Turn Loop Antenna where miniaturization is paramount.

While a vertical loop appeared better than a monopole the omnidirectional capabilities were lost. Horizontal orientation of the loop would restore the omnidirectionality but the horizontal field strength is much less than the equivalent vertical field of the whip due to the ground plane image effect.

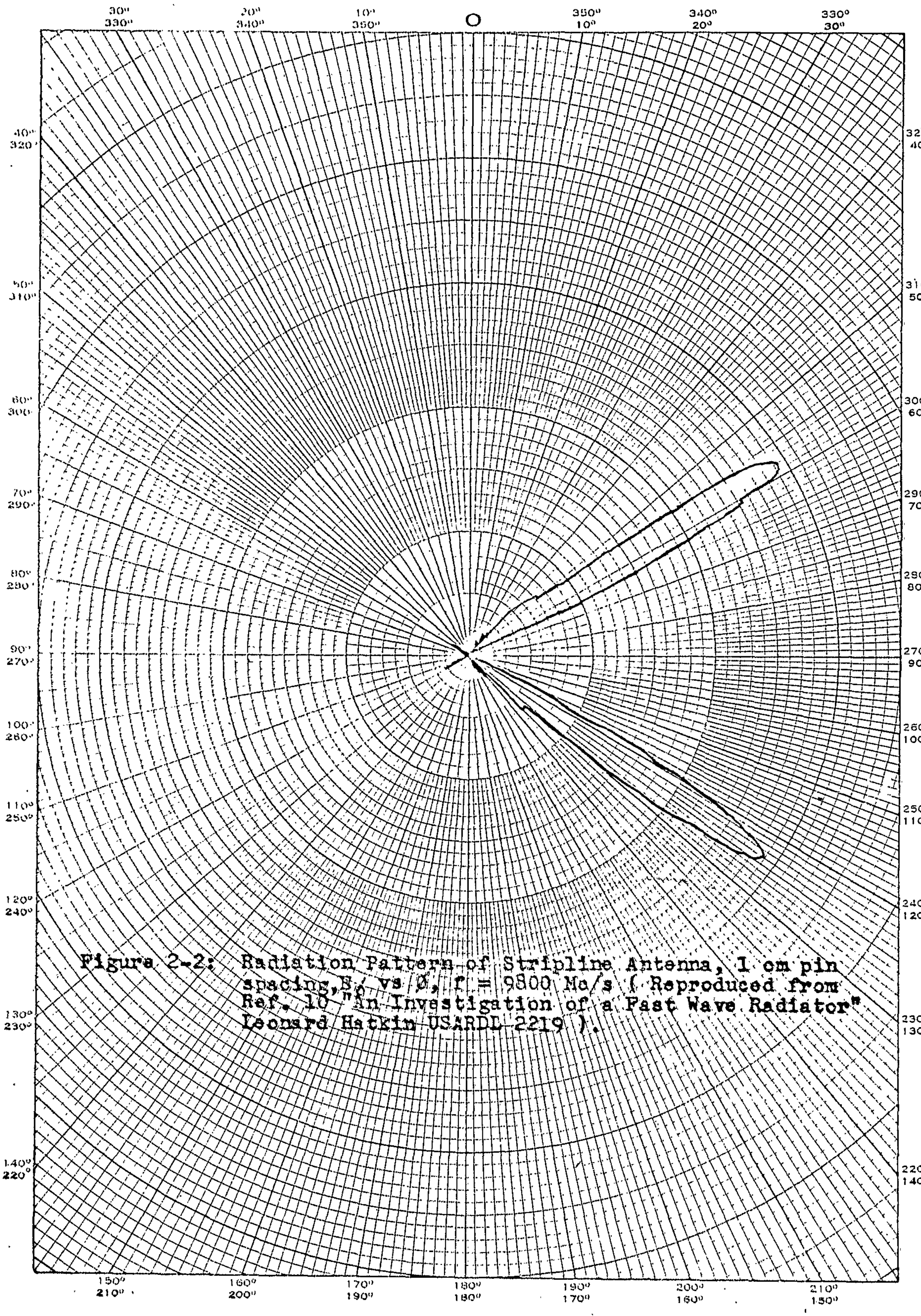

Figure 2-2: Radiation Pattern of Stripline Antenna, 1 cm pin spacing, E_ϕ vs Ø, f = 9800 Mc/s (Reproduced from Ref. 10 "An Investigation of a Fast Wave Radiator" Leonard Hatkin USARDL 2219).

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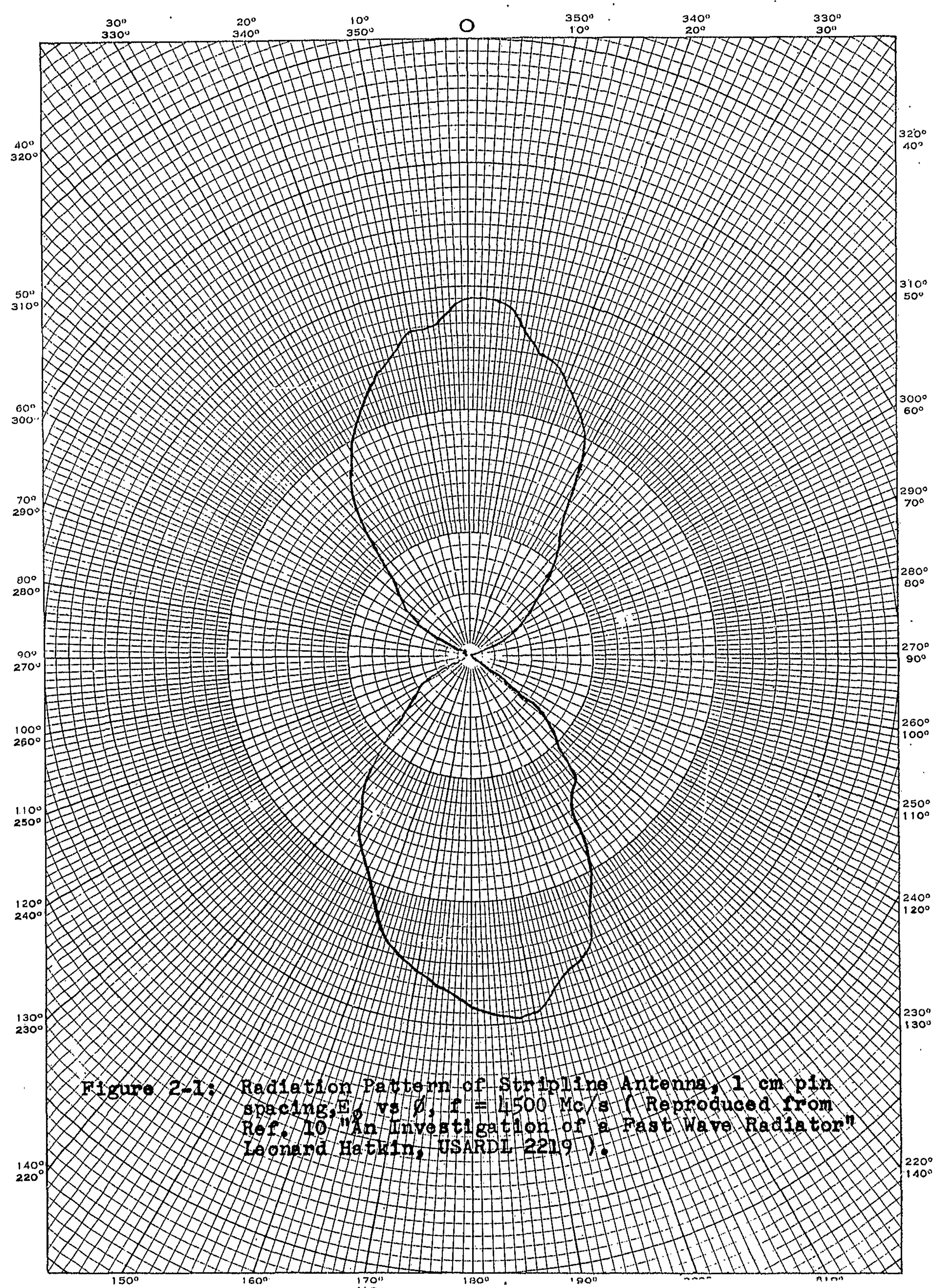
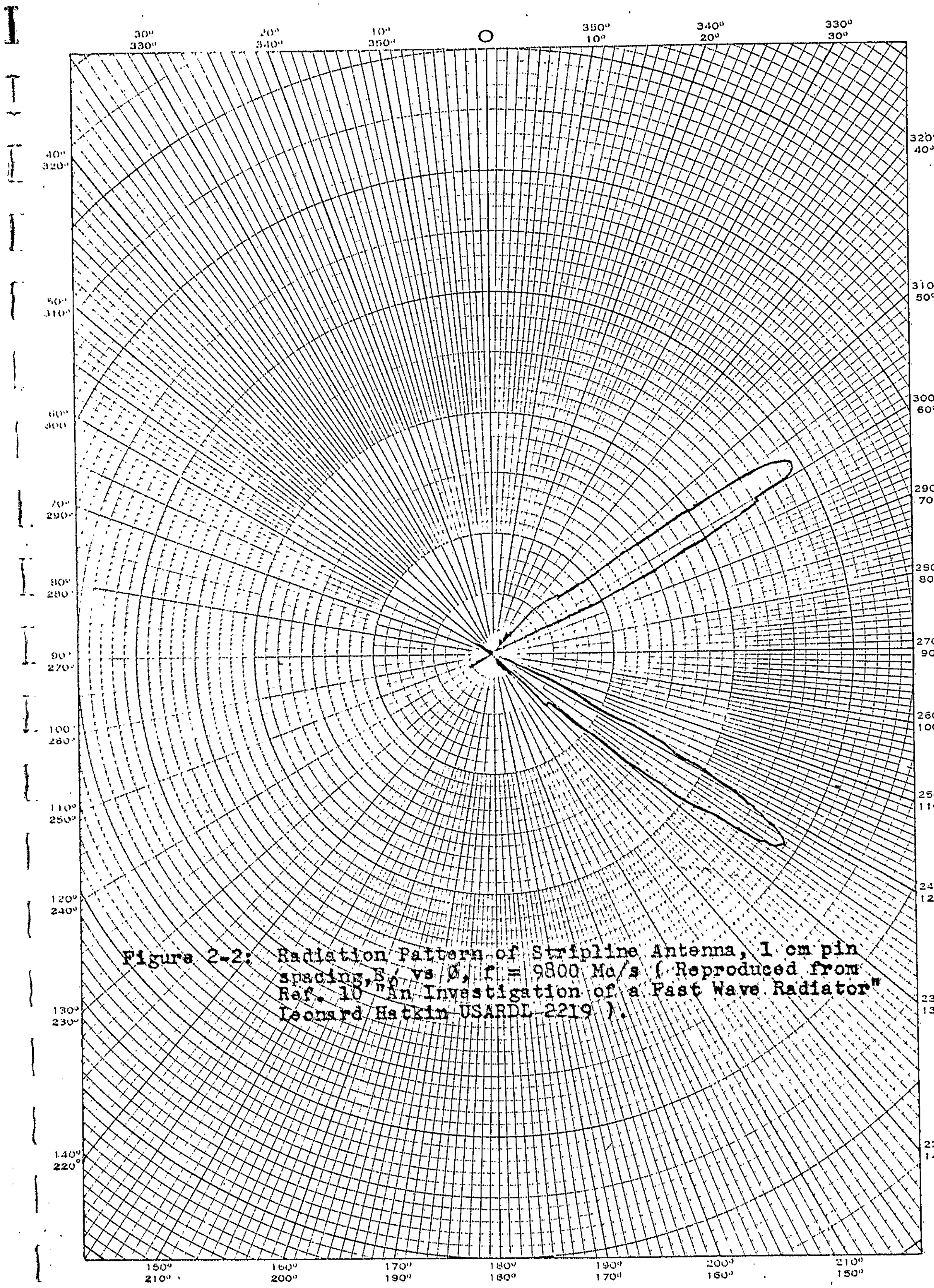


Figure 2-1: Radiation Pattern of Stripline Antenna, 1 cm pin spacing, E_ϕ vs ϕ, f = 4500 Mc/s (Reproduced from Ref. 10 "An Investigation of a Fast Wave Radiator" Leonard Hatkin, USARDL 2219).



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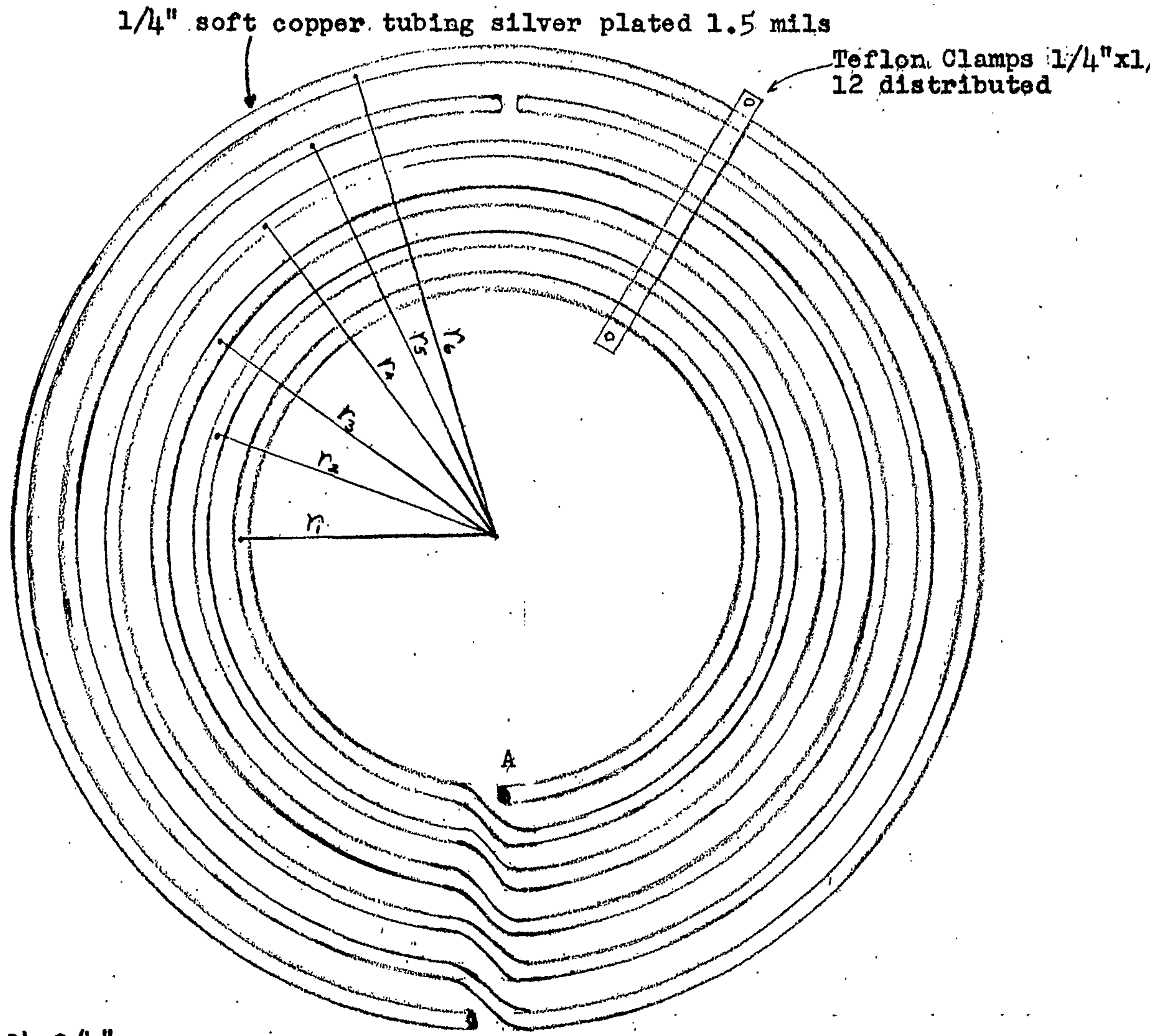

Input Terminals: A - B

$r_1 \approx$ 14-3/4"
$r_2 \approx$ 15-3/16"
$r_3 \approx$ 15-5/8"
$r_4 \approx$ 16-1/32"
$r_5 \approx$ 16-1/2"
$r_6 \approx$ 16-7/8"

Figure 2-3: Six Turn Loop Antenna

2.2 (continued)

It is felt that further work would be necessary to optimize the Multi-Turn Loop Antenna and raise both horizontal and vertical efficiency relative to a 15 foot monopole.

Since this antenna is narrow band, manual or automatic tuning and loop switching would be needed to cover the desired frequency spectrum. However, should the antenna prove effective, the tremendous size reduction may well compensate for the increased antenna system complexity.

2.3 Hula Hoop (DDRR) Antenna

The development of a height reduced antenna, designated as the Hula Hoop or Directional Discontinuity Ring Radiator (DDRR) is reported in Ref. 60 by J. M. Boyer of Northrup, Ventura.

This antenna is composed of a vertical grounded conductor a few electrical degrees high, top loaded with a circular horizontal conductor. The end of this horizontal conductor,which returns close to the position of the vertical conductor, is left open or tuned to ground with a variable capacitor.

The radiation field produced by current in the horizontal conductor and the field produced by induced ground current tend to cancel. The major portion of the radiation field is due to current in the vertical conductor. This provides a radiated wave that is predominately vertically polarized.

The radiation efficiency is reported to be comparable with that of a quarter wave vertical radiator. However, the height reduction of this antenna is accomplished at the expense of a drastic reduction in bandwidth so that tuning becomes very critical.

This antenna is similar to the Multi-Turn Loop Antenna in that for operation over a multi-octave frequency range a complex mechanical switching and tuning system would be required.

2.4 Contact Reports

2.4.1 Mr. C. Phillips, Granger Associates, Palo Alto, California

Mr. Phillips said that the most recent antenna development at Granger is a new lightweight model of their transportable Log Periodic Antenna. The portable antenna, previously reported (Ref. 61) operated over the frequency range of 4 to 30 mc, weighed 440 pounds and had a storage volume of 75 cubic feet.

2.4.1 (continued)

The new model of this antenna operates over the same frequency range, features a considerable reduction in weight and erection time over the previous model. Both models of this antenna are of the Log Periodic Vee type and are supported by a single tower. These antennas are horizontally polarized and, therefore, have an elevation pattern beam that is 27° to 50° above the horizon. This type of elevation pattern is ideal for point to point sky wave communication.

Because of the high beam angle of horizontally polarized antennas, we have not considered them to be suitable to fill the Marine Corps needs, where ground wave communications as well as sky wave communications will be required.

2.4.2 Mr. Harold Leach, Alford Manufacturing Company, Boston, Mass.

The Alford Manufacturing Company developed the Broadband Slotted Ring Antenna used for television broadcasting. This antenna features high gain and a simple feed system. Alford also manufactures a line of Broadband Dipole Antennas, however, Mr. Leach said that they have not developed any frequency independant types and that they are now concentrating on the manufacture and sale of antenna and transmission line test equipment. These include slotted lines, automatic impedance plotting equipment, automatic SWR and transfer characteristic meter and transmission line components.

2.4.3 Professor John D. Dyson, Electrical Engineering Research Laboratory, University of Illinois.

Although most of the known types of frequency independent antennas were developed at this laboratory, Professor Dyson stated that no new types have been developed during this report period and that work there has been concentrated on the investigation of the Periodic Antenna. It is felt that after this antenna is completely understood that it will be a simple step to bridge the gap to the Log Periodic Antenna.

2.4.4 Dr. Helmut Brueckmann, Mr. Robert Kulinyi, United States Army Research and Development Laboratory, Fort Monmouth, New Jersey

Interest at U.S.A.R.D.L. is centered around size reduced antennas for vehicle and man pack use. It is felt that the past few years have produced smaller and lighter radio equipment, but that similar advances in antenna design have not been made.

2.4.4 (continued)

In an effort to obtain an efficient antenna that is drastically reduced in size, the Army has funded a Ferrite Antenna Development Program. An antenna to fill the vehicle and man pack requirement would be a minimum size narrow band antenna, capable of tuning to the desired frequency rather than a larger broadband antenna.

3.0 SCALE MODEL EVALUATION

Interim study report (Ref. 61) reported on the evaluation of two scale model antennas: The Log Conical Spiral and Scimitar No. 1. In the succeeding and final interim of the program under Contract NOm 72423, many more scale models were constructed and evaluated. These included two new versions of the Scimitar. Several UHF models and a VHF model of a new type, the Sinuous Log Periodic were also evaluated. The construction and evaluation of these scale models is discussed in the following paragraphs:

3.1 Scimitar No. 2 and No. 3

Both the inner and outer curves of the Scimitar (See Figure 3-1) are defined by the spiral equation:

$$r = Ke^{a\phi}$$

where r = the radius vector from the origin 0 to any point on the spiral

K = a constant and is equal to the length of the radius vector at $\phi \pm 0$ (K is the same for both inner and outer curves)

a = a constant that determines the rate of expansion of the spiral

ϕ = angular rotation of the spiral in radians

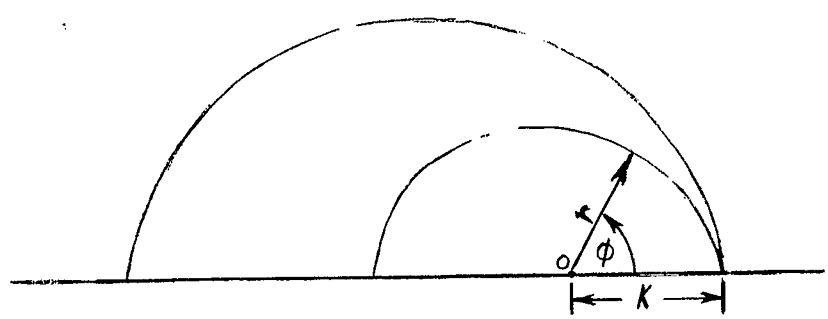

Figure 3-1: Geometry of Scimitar

The first model of the Scimitar reported in the interim report (Ref. 61) was designed with the origin of both inner and outer spiral curves located

3.1 (continued)

on the ground plane. The parameter "a" was chosen to be zero and 0.46 for the inside and outside spiral curves respectively. The subsequent choice of K = 13.7 inches described an antenna 32 inches high, 72.7 inches long and with the inside curve describing a semicircle of radius 13.7 inches. The results of input admittance and radiation pattern measurements on this antenna were discussed in the interim report.

In an effort to reduce the length of the antenna a second model (Scimitar No. 2) was constructed with the spiral origin located above the ground plane (see Figure 3-2). The inside curve with "a" still zero and K = 10.6 inches subtended an angle of 270° at the origin. The value of "a" for the outside curve which was selected on the basis of maintaining the same height as Scimitar No. 1 (i.e., 32 inches) was found to be 0.35.

The input admittance plot of this antenna over a 7:1 frequency range is shown in Figure 3-4. The radiation patterns over the frequency range 50-480 mc are shown in Figure 3-6 and 3-7. The admittance measurements demonstrate that this antenna can operate over a 7:1 frequency range without exceeding a 2:1 VSWR when fed with a 50 ohm coaxial line and a 4:1 impedance transformer. The radiation patterns are also similar to those of Scimitar No. 1.

This design resulted in a considerable reduction (24%) in antenna length. Its total length is only 55.3 inches compared to 72.7 inches for Scimitar No. 1 antenna. A proposed mechanical design of a full size engineering model Scimitar No. 2 antenna for operation over the frequency range of 6 to 42 mc is included in Section 4 of this report.

Subsequent to the completion of Scimitar No. 2 scale model tests, it was decided to investigate the effect of changing the size of the inside curve, to improve higher frequency pattern. Scimitar No. 1 model was modified by altering the radius of the inside curve to 6.85 inches as shown in Figure 3-3.

The input admittance plot of this antenna (named Scimitar No. 3) is shown in Figure 3-5. The lowest frequency at which the input admittance is a usable value is higher than that for either Scimitar No. 1 or No. 2. Alteration of the inside curve had much less effect on the radiation patterns (shown in Figure 3-8 and 3-9) than was expected. These patterns appeared very similar to those of Scimitar No. 1 and No. 2. However, it is apparent from the input admittance measurements that an antenna of this design for a given lowest frequency of operation would be larger than either of the two preceding models.

3.1 (continued)

Although time did not permit further investigation along these lines, these brief tests indicate that the low frequency limit of Scimitar No. 2 antenna may be extended slightly lower by some increase in the size of its inside curve.

3.2 Sinuous Log Periodic Antenna

3.2.1 Derivation of Geometric Function

The concept of a Sinuous Log Periodic Antenna was derived from the projection of a Log Conical Spiral on a plane parallel to the cone axis. The derivation of the equation for this two dimensional curve follows (see Figure 3-10).

Let OP be the radius vector which defines the locus of the Log Conical Spiral.

where $OP = r = r_o e^{a\phi}$

where ro = constant = radius vector at commencement of spiral

$a = \frac{\sin \theta o}{\tan \psi}$, where θo = half cone angle

ψ = acute angle formed by intersection of radius vector and spiral

ϕ = angular rotation of spiral in radians

Let the plane AOB have rectangular coordinates x and y referred to the origin O, where x and y run parallel to OB and BA respectively. Then the projection of P on plane AOB is given by:

$$x = OC = r \cos \theta o = r_o e^{a\phi} \cos \theta o \qquad (1)$$

$$y = CP' = DP = CP \sin \phi = r \sin \theta o \sin \phi = r_o e^{a\phi} \sin \theta o \sin \phi \qquad (2)$$

$$\text{Now } e^{a\phi} = \frac{x}{r_o \cos \theta o} \quad \text{and} \quad \phi = \frac{\ln\left(\frac{x}{r_o \cos \theta o}\right)}{a}$$

$$y = \frac{x}{\cos \theta o} \sin \theta o \sin \left[\frac{\ln\left(\frac{x}{r_o \cos \theta o}\right)}{a} \right]$$

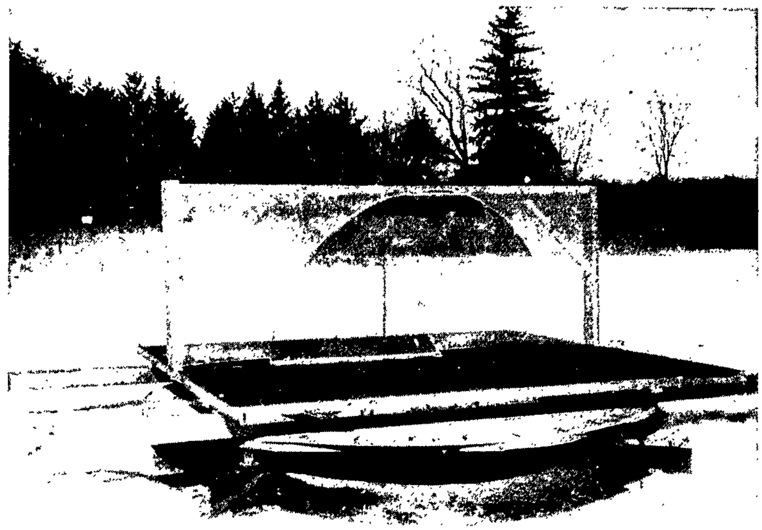

Figure 3-2: Scimitar Antenna No. 2

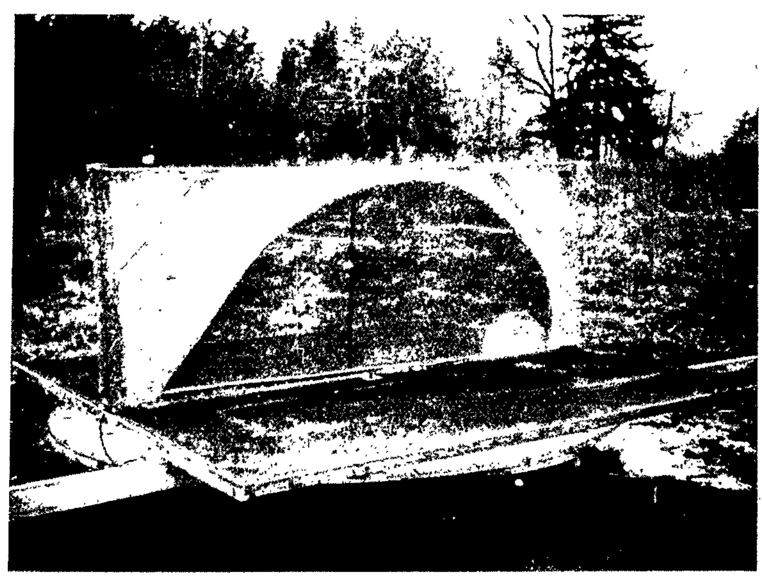

Figure 3-3: Scimitar Antenna No. 3

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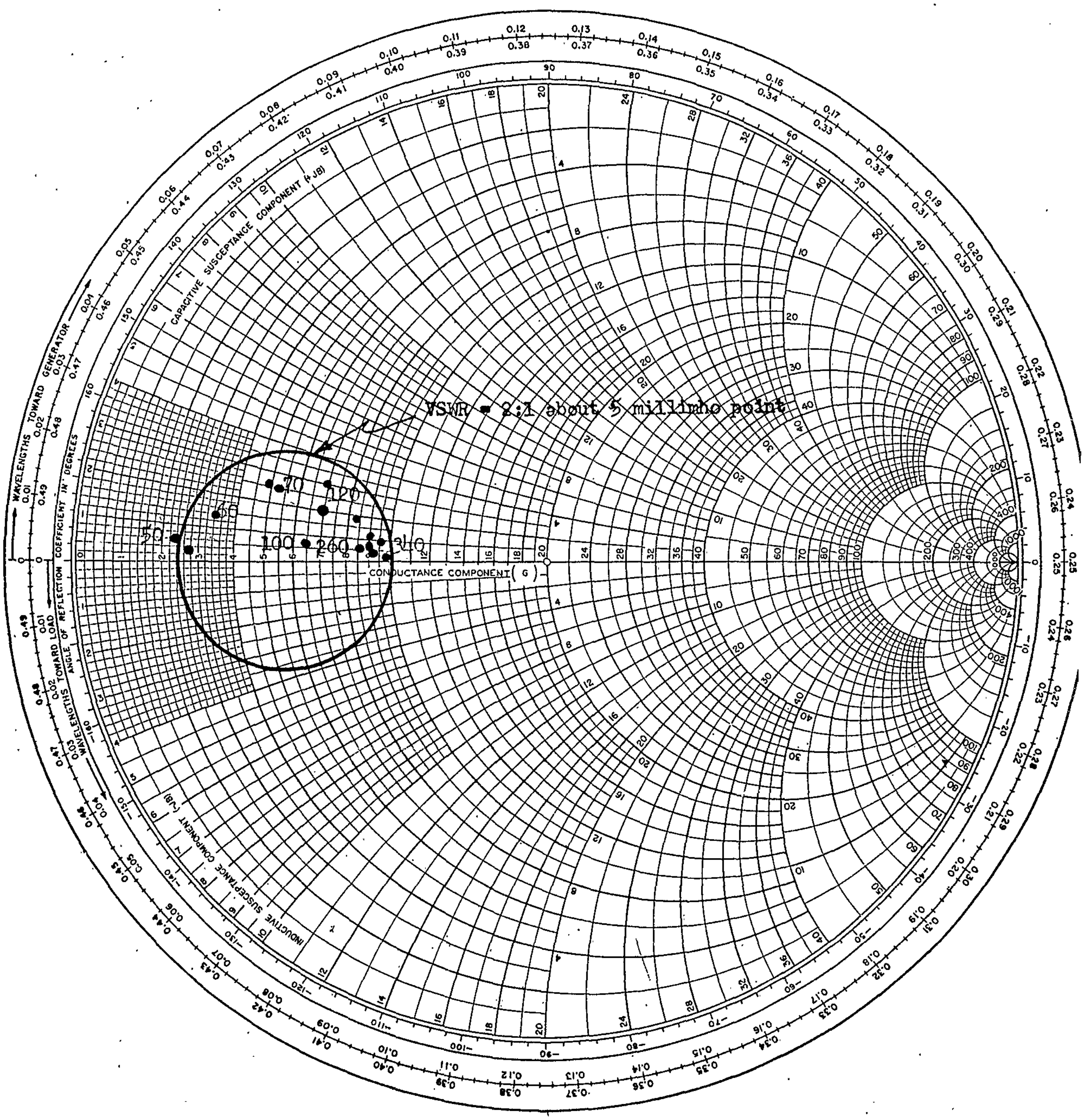

Figure 3-4: Input Admittance Plot of Scimitar No. 2 (50-340 mc)

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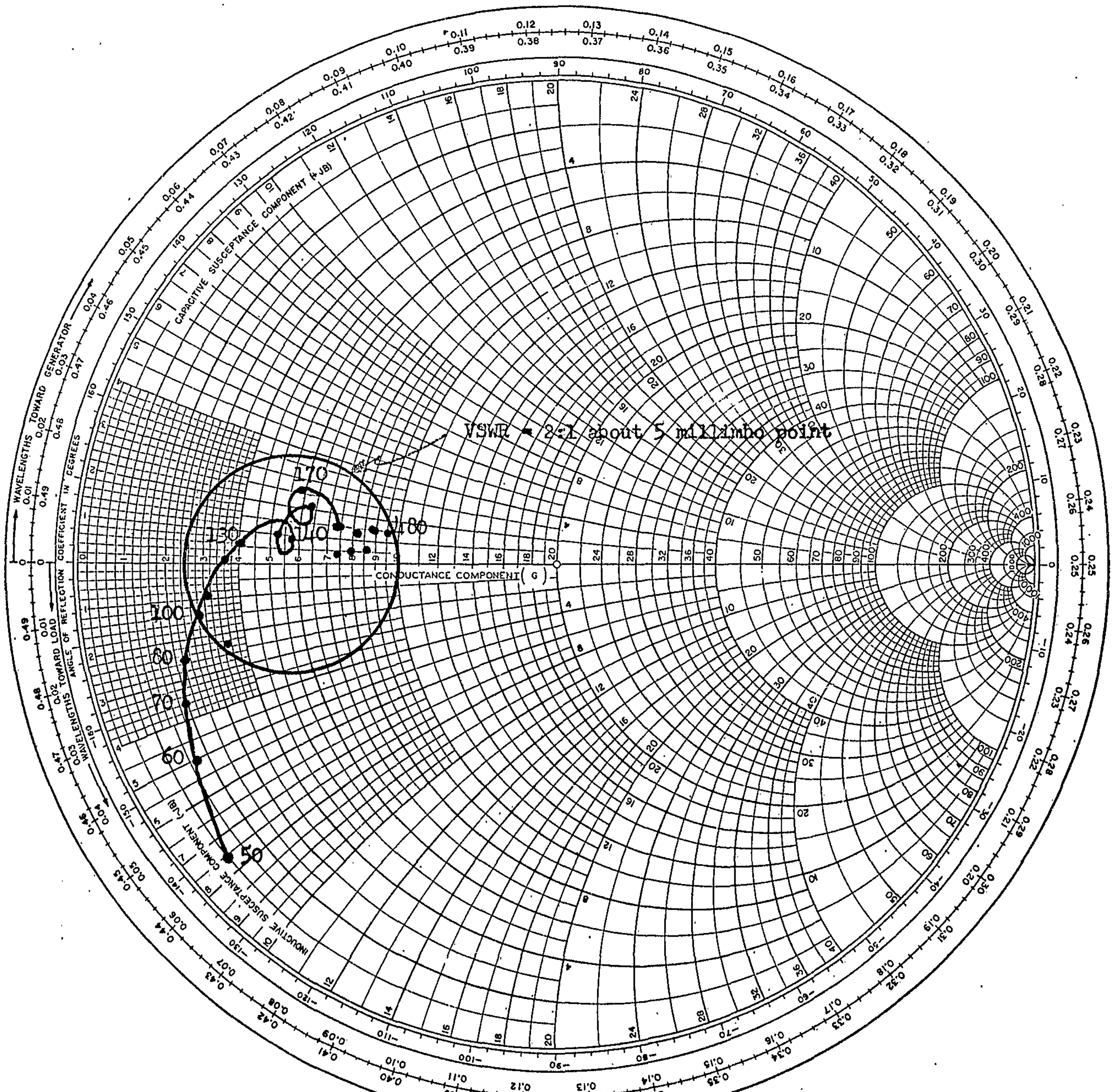
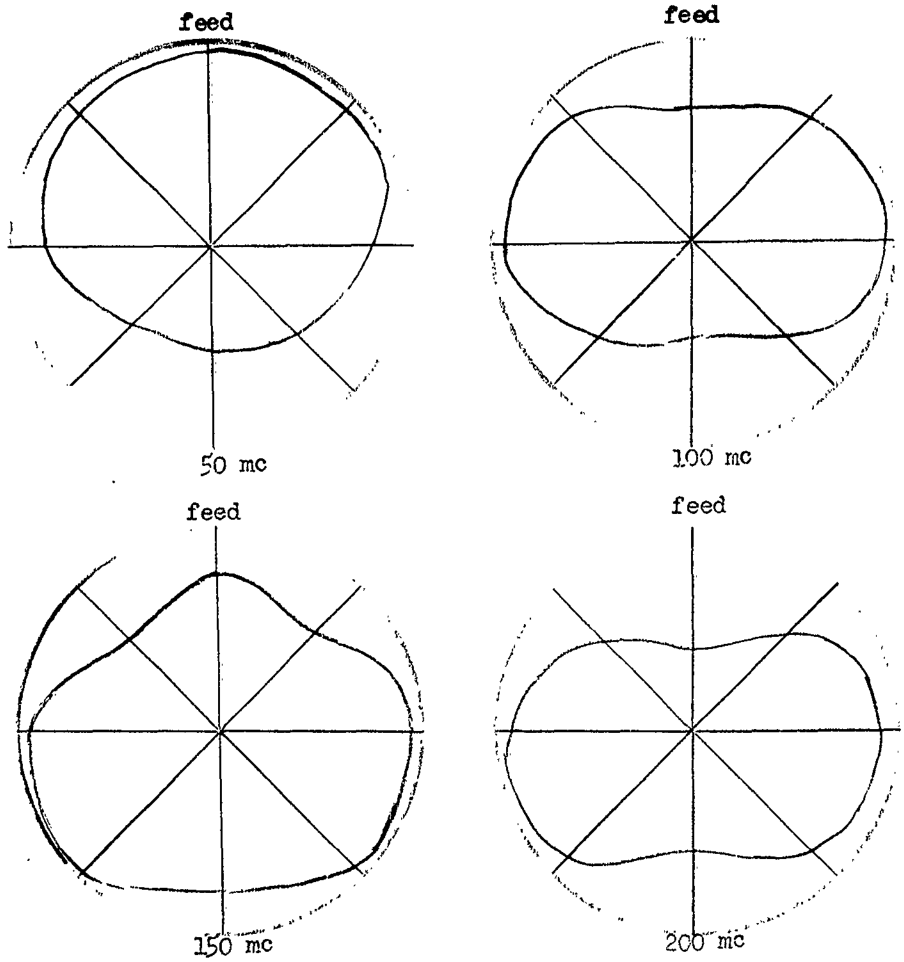
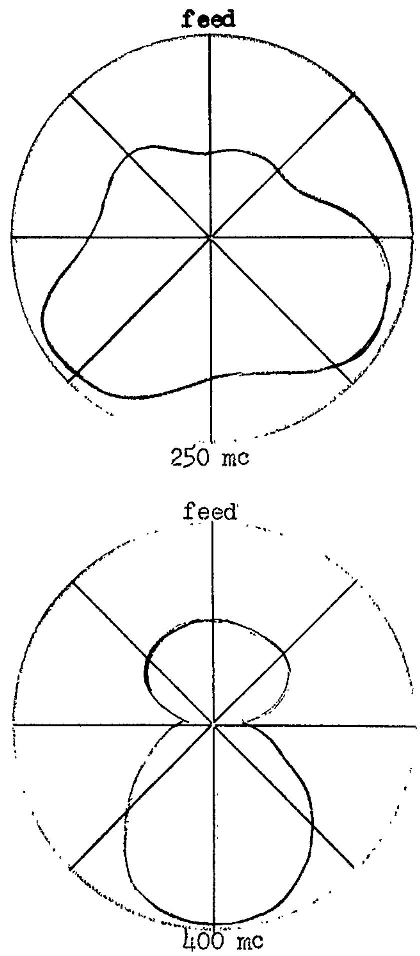


Figure 3-5: Input Admittance Plot of Scimitar No. 3 (50-480 mc)



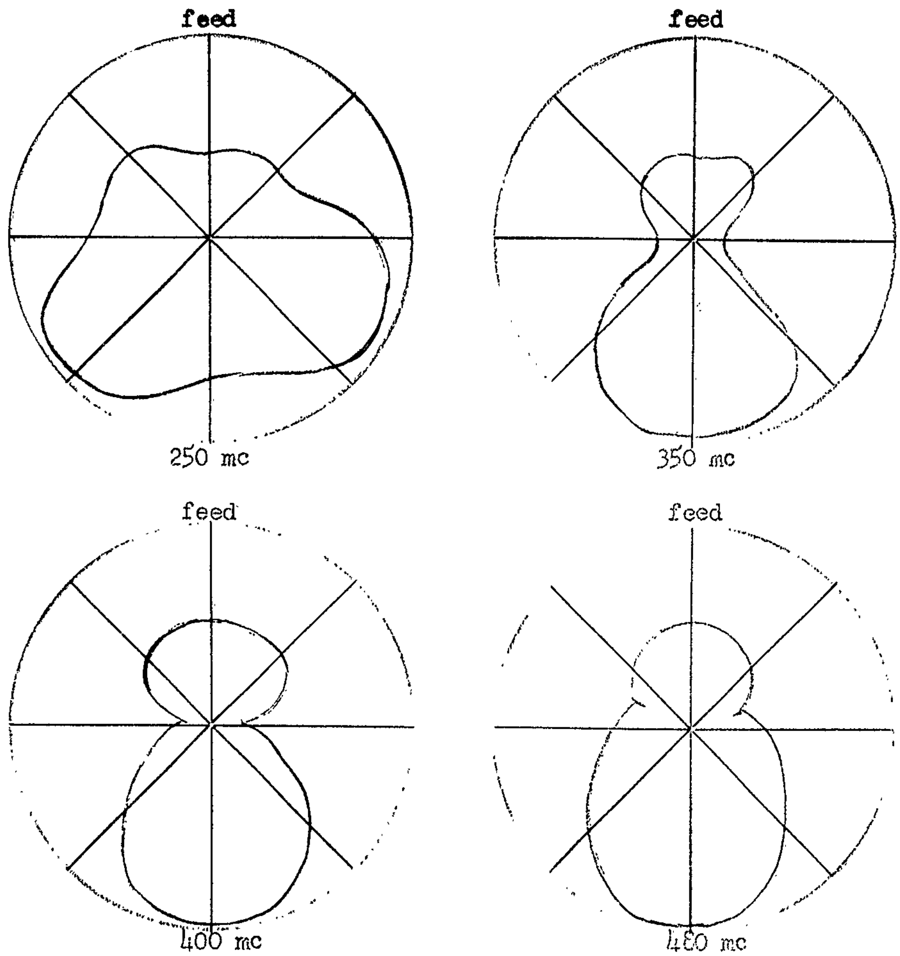
Scale = normalized voltage: 0 to 1.0

Figure 3-6: Radiation Patterns of Scimitar No. 2
(K = 10.6 inches, a = 0 and 0.35)



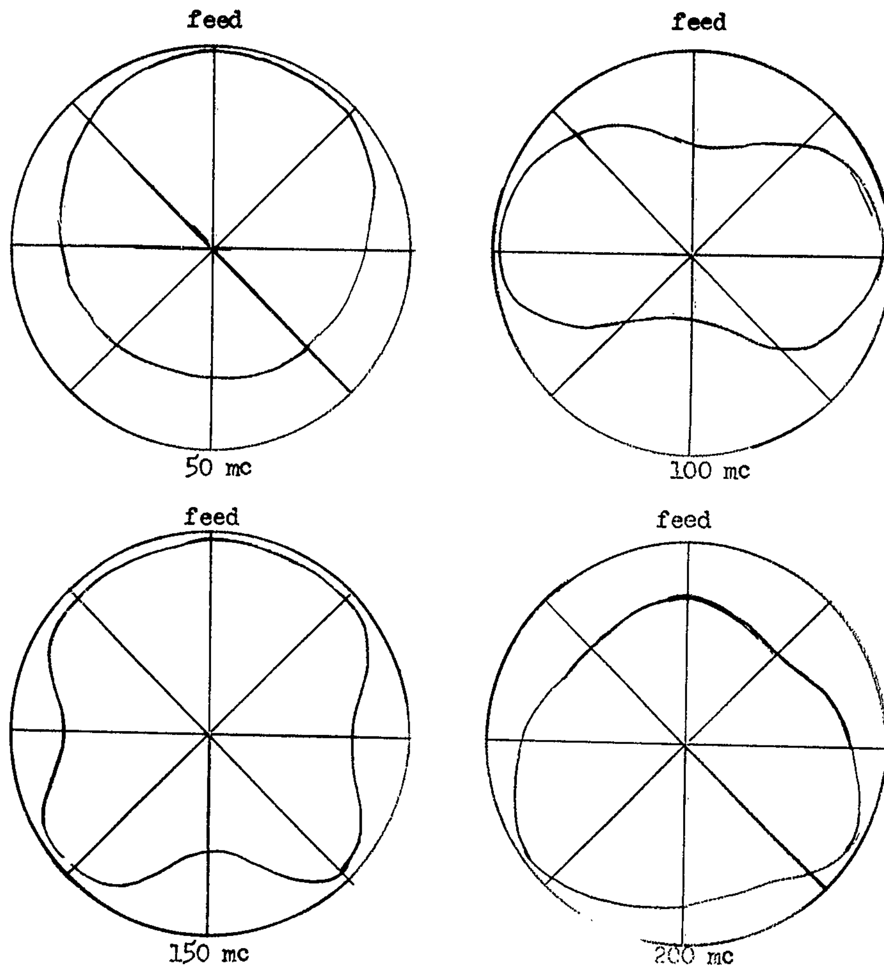
Scale = normalized voltage: 0 to 1.0

Figure 3-7: Radiation Patterns of Scimitar No. 2
(K = 10.6 inches and a = 0 and 0.35)



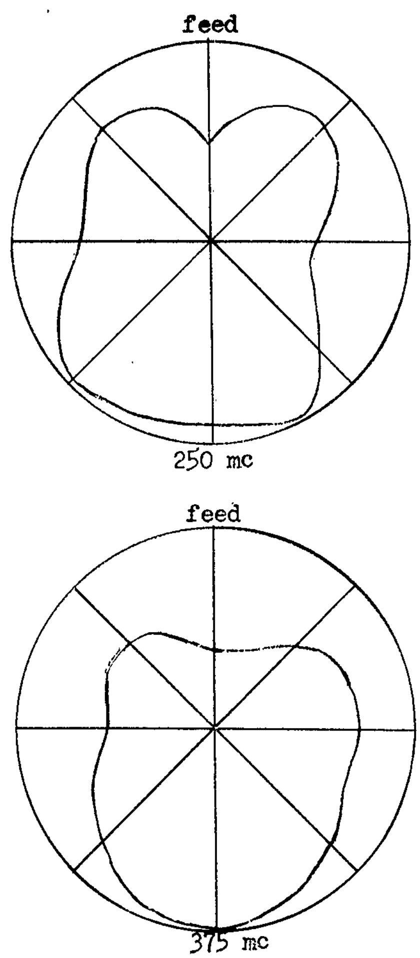
Scale = normalized voltage: 0 to 1.0

Figure 3-7: Radiation Patterns of Scimitar No. 2
(K = 10.6 inches and a = 0 and 0.35)



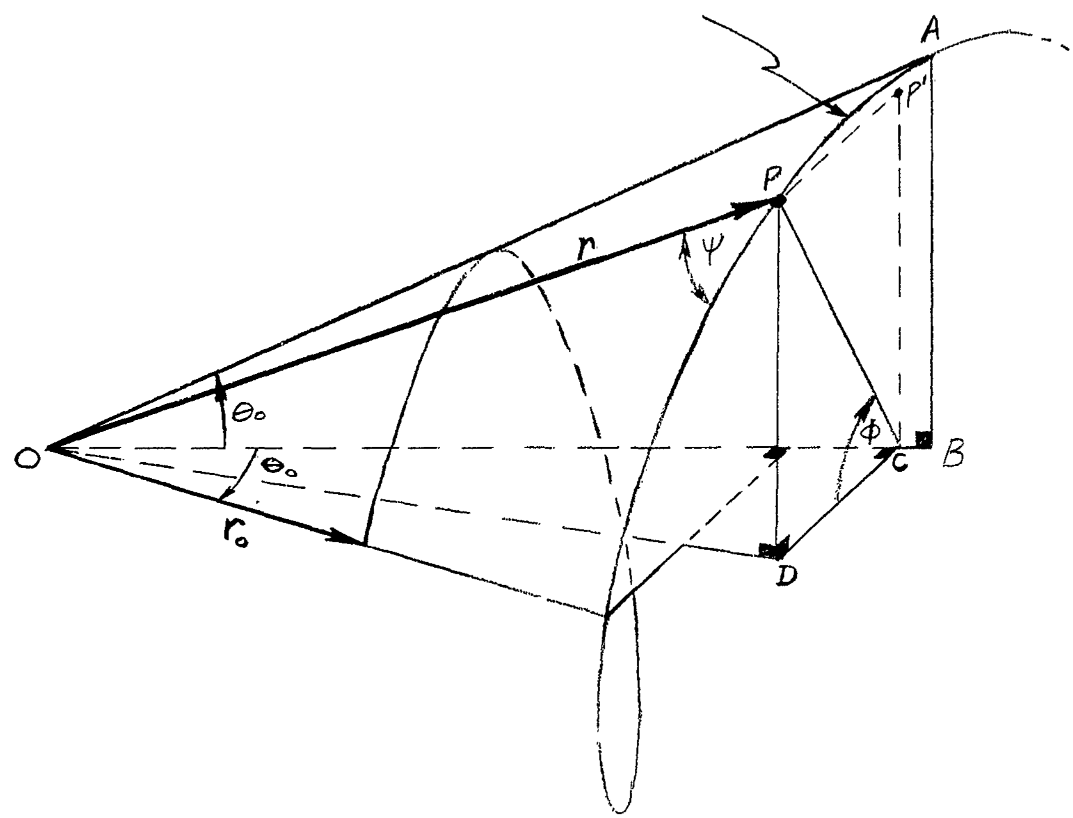
Scale = normalized voltage: 0 to 1.0

Figure 3-8: Radiation Patterns of Scimitar No. 3



Scale = normalized voltage: 0 to 1.0

Figure 3-9: Radiation Patterns of Scimitar No. 3


A
P'
P
r
ψ
θ_o
O
θ_o
r_o
ϕ
C
B
D

3.2.1 (continued)

Since r_o and Θo are constants, let $\tan \Theta o = K_1$

$$\frac{1}{r_o \cos \Theta o} = K_2$$

Then the equation may be simplified to read:

$$y = K_1 \; x \sin \left[\frac{\ln (K_2 \, x)}{a} \right] \qquad (3)$$

From (2) it is seen that the function peaks where:

$$\frac{dy}{d\phi} = 0$$

i.e., where $\tan \phi = \frac{1}{a} = \frac{\tan \psi}{\sin \Theta o}$

For small Θo, it can be seen that the function will have positive and negative peaks approximately where $\phi = (2n + 1) \frac{\pi}{2}$, $n = 0, \pm 1, \pm 2$, etc.

3.2.2 UHF Model Evaluation

Experience gained during the testing of the scale models of the Log Conical Spiral and the Scimitar Antenna indicated that evaluation of different antenna configurations could be accomplished in much less time on smaller (UHF) models. Although the accuracy of measurement is reduced slightly at the high frequencies, tests on the UHF models would be sufficiently accurate to determine if a given radiating configuration would provide frequency independent operation.

The first UHF scale model of the Sinuous Log Periodic was designed to operate from 600 to 1800 mc. The half angle "α" was chosen to be the same as the cone half angle "Θo" used on the Log Conical Spiral (Ref. 61). The number of cycles chosen yielded the design parameter $\tau = 0.825$ and $\sigma = 0.09$

where $$\tau = \frac{r_{n\pi}}{r_{(n+1)\pi}} = e^{-a\pi}$$

$$\sigma = \frac{r_{(n+2)\frac{\pi}{2}} - r_{n\frac{\pi}{2}}}{4 r_{(n+2)\frac{\pi}{2}}} \cdot \cot \Theta_o = \frac{\cot \Theta_o}{4} \left[1 - e^{-a\pi} \right]$$

3.2.2 (continued)

The input admittance plot (Figure 3-11) shows the plotted points to be closely clustered when the antenna is operated above ground as shown in the insert. This antenna is called UHF Model No. 1.

In order to observe the effect of placing a boom along the axis of the model, a wire was run along the axis and soldered to each intersecting conductor as shown in the insert of Figure 3-12 (UHF Model No. 2). As indicated by the input admittance plot, frequency independent operation is maintained.

In order to reduce the height of the longest element when the antenna is operated above ground, the elements on one side of the boom were bent to form an angle of 90° with the elements on the other side of the boom. This antenna was then operated with one set of elements vertical and the other set parallel to the ground plane as shown in the insert of Figure 3-13 (UHF Model No. 3). The admittance plot shows that this antenna has a performance similar to UHF Model No. 2. Removal of the boom from the folded antenna deteriorated its performance; this is indicated by the less closely clustered admittance points (greater VSWR) shown in Figure 3-14 (UHF Model No. 4).

An effort was also made to reorient the horizontal elements into the vertical plane with the proper phase relationship so that the entire antenna could be supported from a single mast. As a first attempt to accomplish this, UHF Model No. 5 was constructed by utilizing RG58/U coaxial cable as the radiating conductor with element phasing effected by transposition of inner and outer conductors at each element junction, as illustrated in the insert of Figure 3-15. Although the input admittance of this model did not indicate a good performance, subsequent tests on other models indicated a potential improvement with the use of a boom and an air dielectric coaxial cable, which would maintain equal phase velocities inside and outside of the element. Time did not permit further evaluation of this discovery.

Subsequent to the completion of the coaxial cable model tests, 14 other UHF models were constructed and tested for input admittance variations over the 300 to 900 mc frequency range. The input admittance plots of two of the better performers are shown in Figures 3-16 and 3-17 (UHF Models 6 and 7 respectively). The results observed on the remaining 12 models were considered sufficiently discouraging to preclude their discussion in this report.

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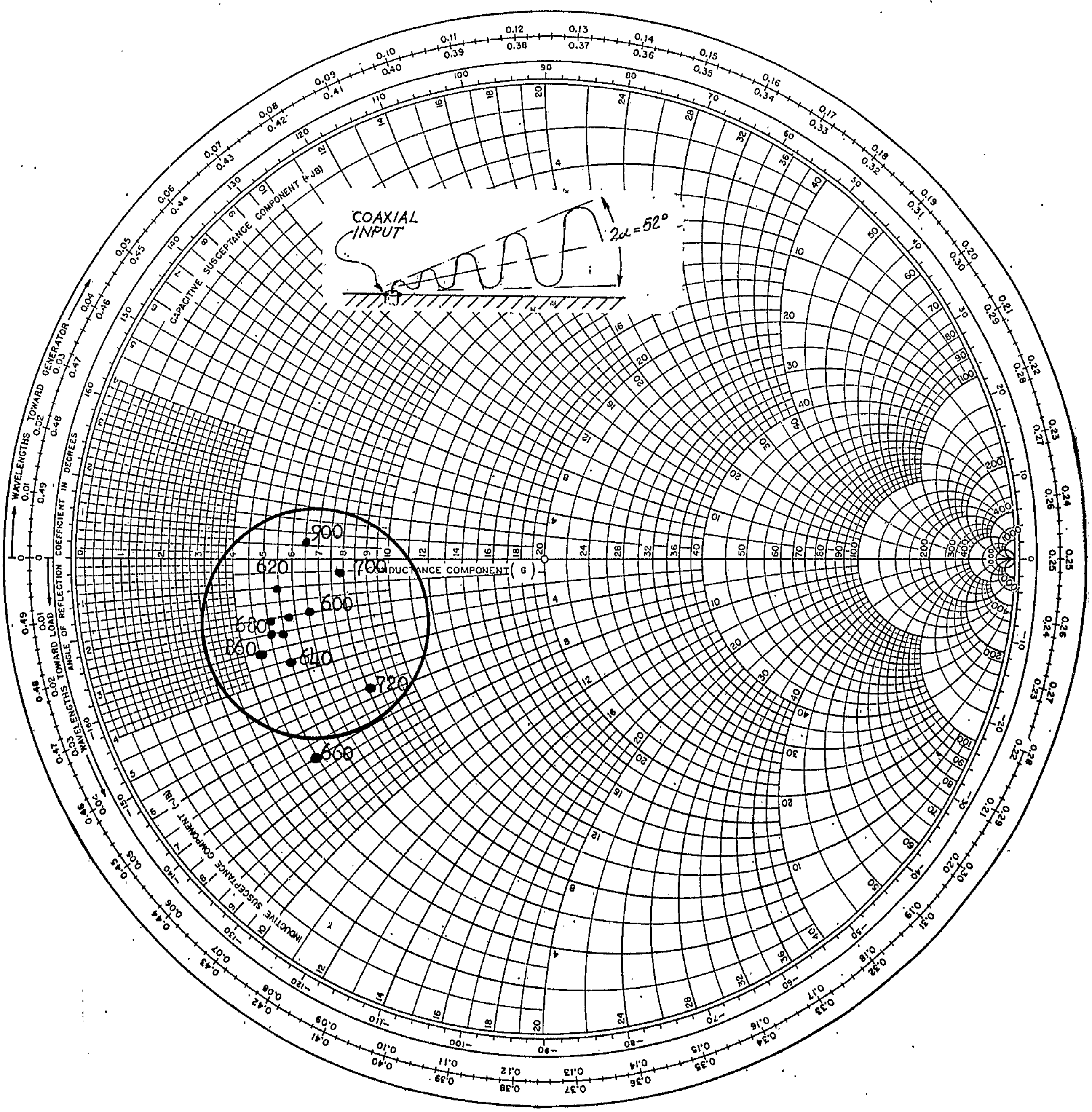

Figure 3-11: Input Admittance Plot of UHF Model #1 of Sinuous Log Periodic Antenna

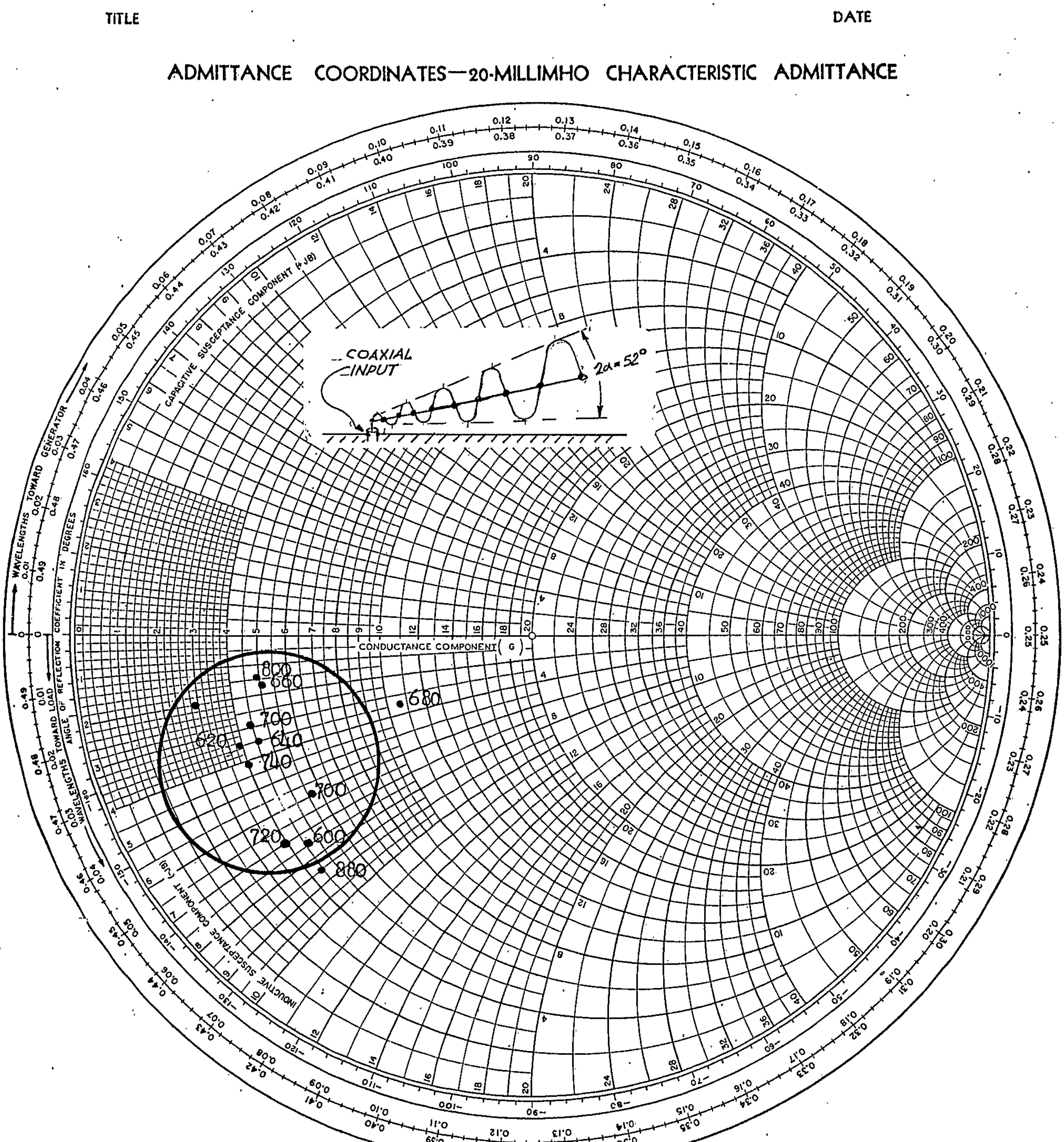

Figure 3-12: Input Admittance Plot of UHF Model #2 of Sinuous Log Periodic Antenna

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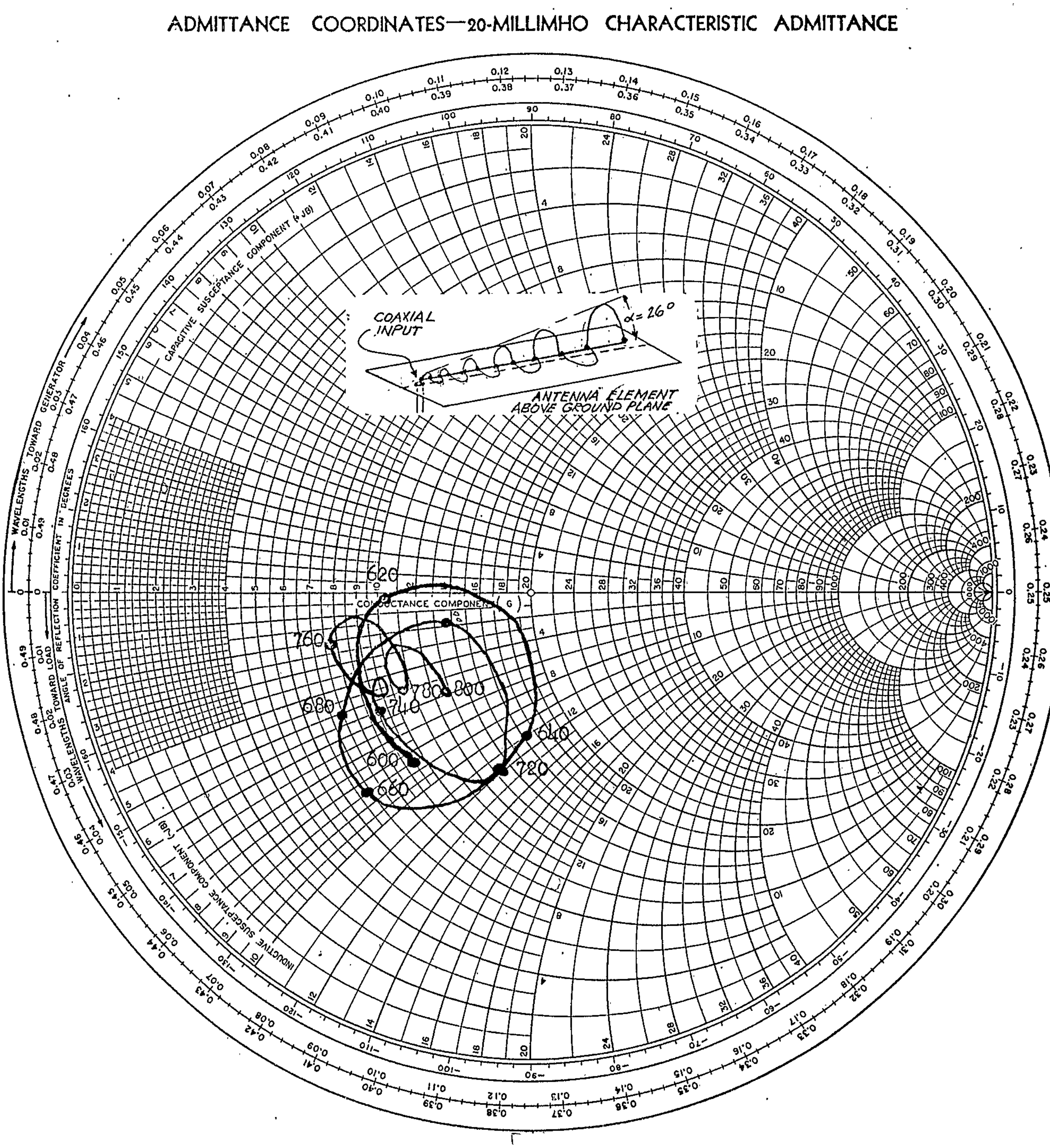

Figure 3-13: Input Admittance Plot of UHF Model #3 of Sinuous Log Periodic Antenna

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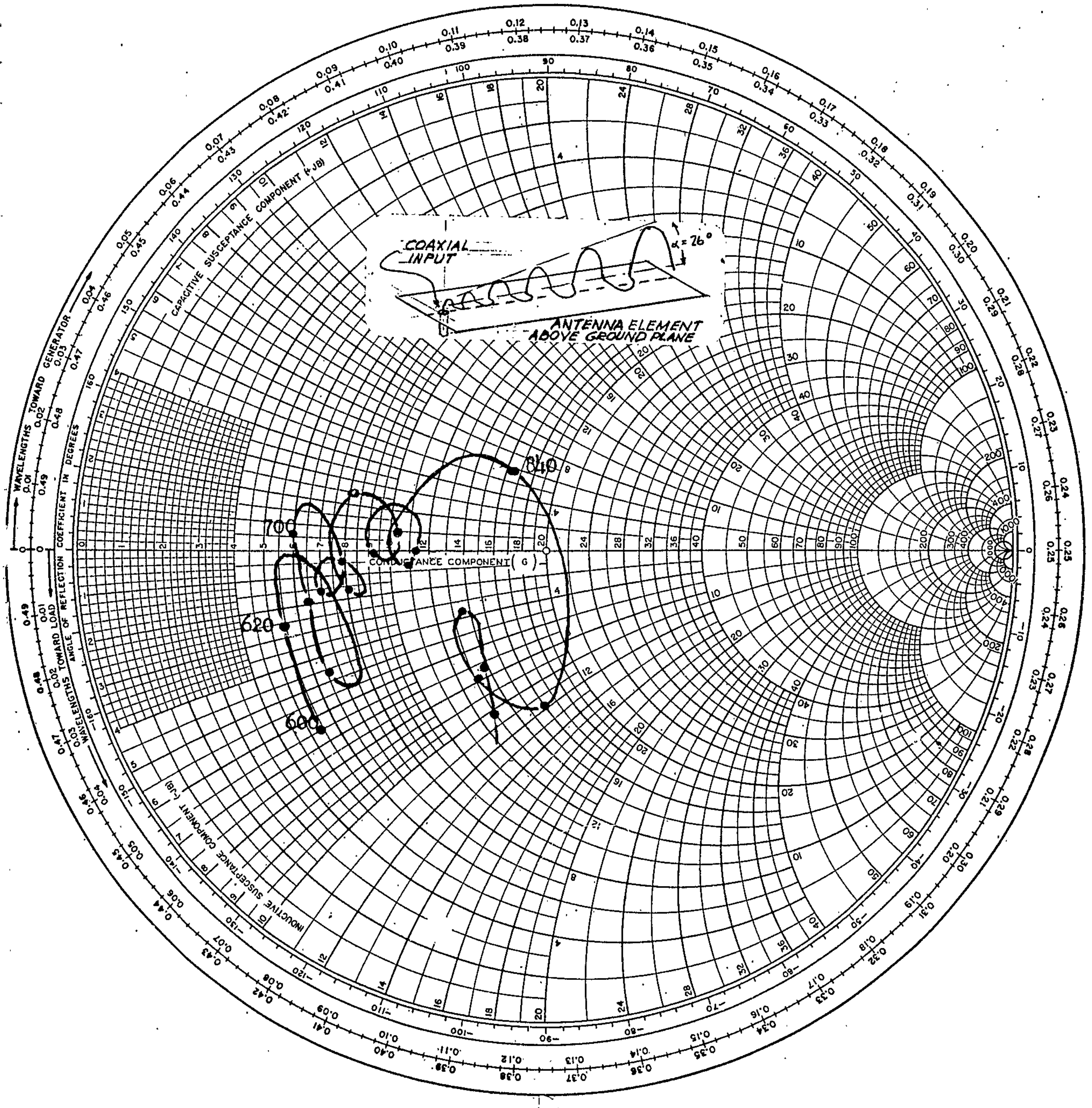

Figure 3-14: Input Admittance Plot of UHF Model #4 of Sinuous Log Periodic Antenna

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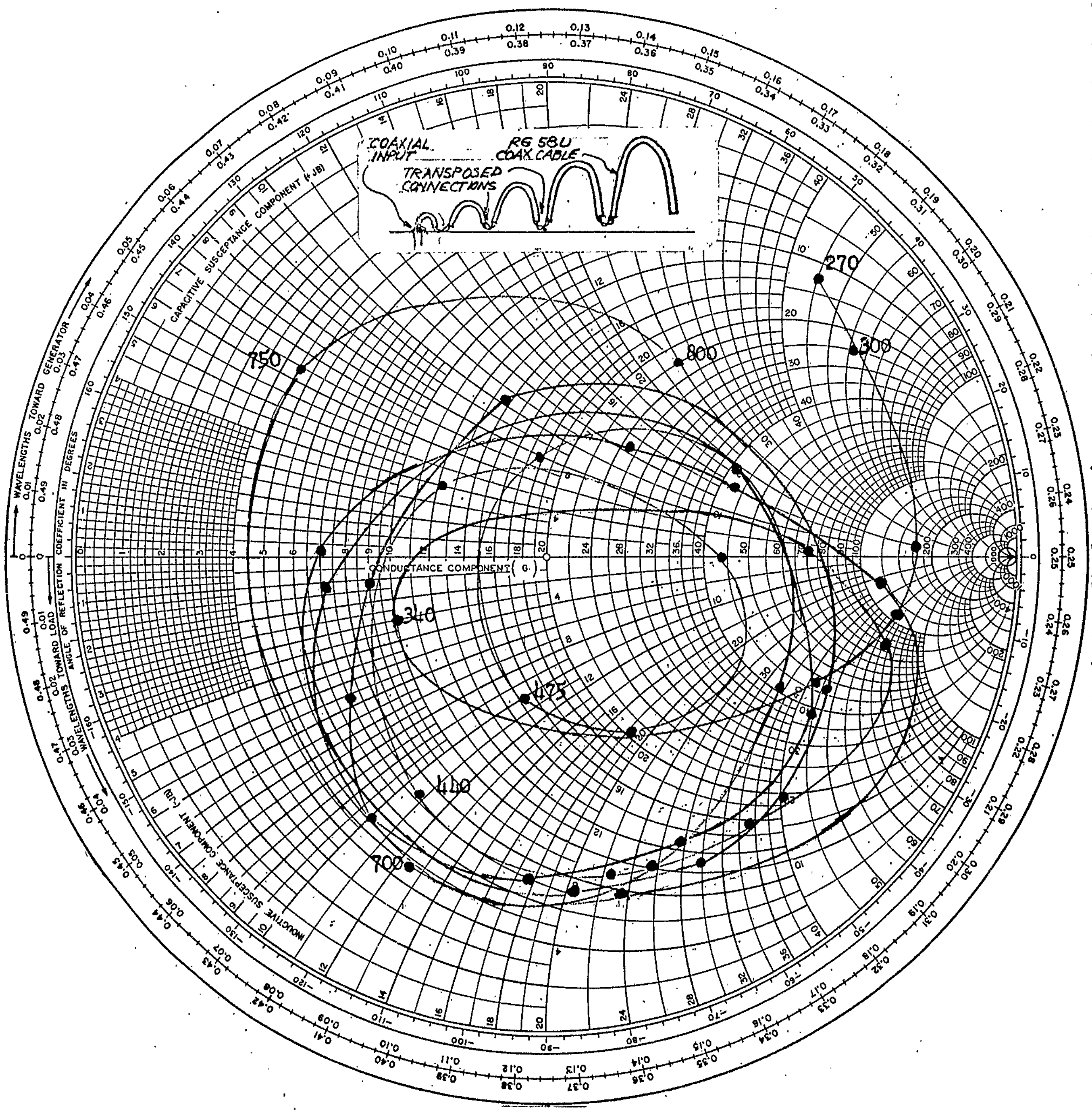

Figure 3-15: Input Admittance Plot of UHF Model #5 of Sinuous Log Periodic Antenna

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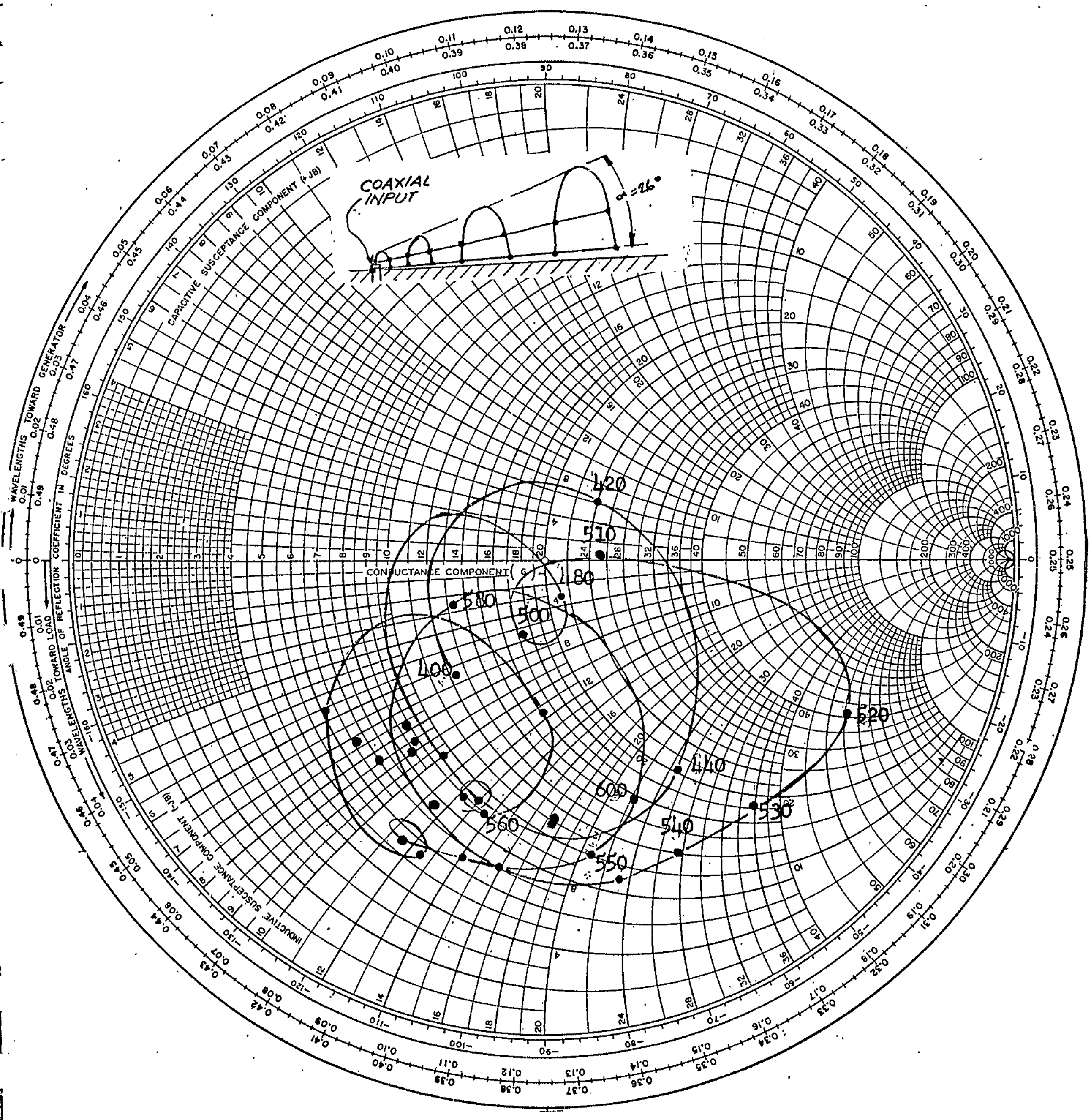

Figure 3-16: Input Admittance Plot of UHF Model #6 of Sinuous Log Periodic Antenna

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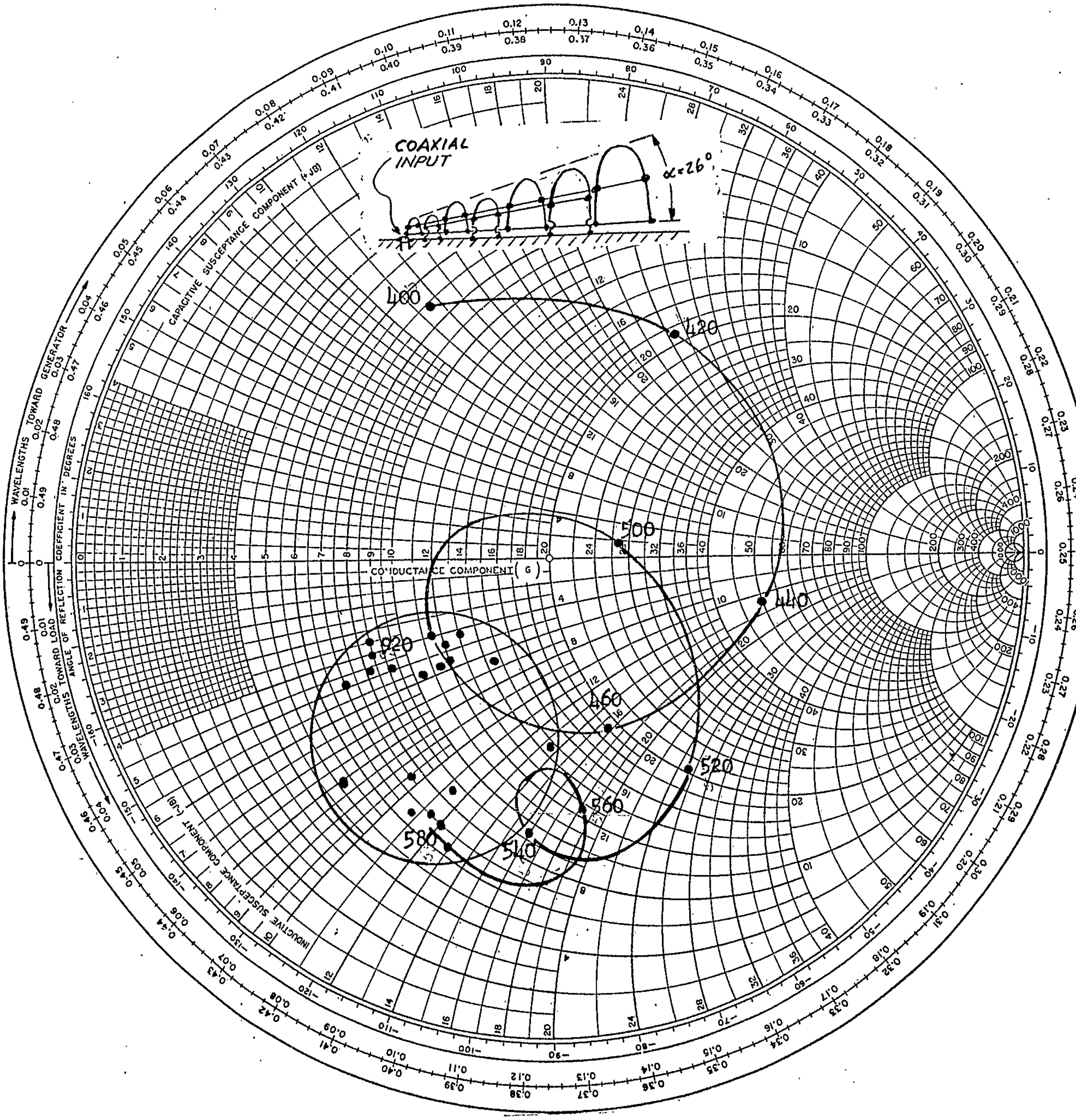

Figure 3-17: Input Admittance Plot of UHF Model #7 of Sinuous Log Periodic Antenna

3.2.2 (continued)

From the preliminary results of the various UHF models tested, it is apparent that Models 2 and 3 would yield the most promising configurations. Therefore, it was decided to construct a VHF model of these configurations in order to perform more elaborate tests in the lower frequency range.

3.2.3 Construction of VHF Model

The Sinuous Log Periodic scale model was constructed to operate over the frequency range 75-375 mc. The "θo" and "a" parameters of the complex sine function derived in paragraph 3.2.1 were chosen to be identical to those in the Log Conical Antenna described in the preceding semi-annual report (Ref. 61). The lower frequency design limit was chosen by making the largest peak amplitude of the sine function equal to one-quarter wavelength at the lowest frequency; $\lambda/4$ at 75 mc is 39.3 inches. The subsequent occurrence and amplitudes of the sine function peaks are then determined by the "a" and "θo" parameters. The smallest peak amplitude which would allow 375 mc to be included within the design frequency range was found to be 7.5 inches ($\lambda/4$ at 393 mc).

The x and y coordinates which were used to plot the sine function were computed (see below) and subsequently tabulated.

$$x = r_o e^{a\phi} \cos \theta o$$

$$y = r_o e^{a\phi} \sin \theta o \sin \phi$$

where $a = \dfrac{\sin \theta o}{\tan \psi}$

θo and ψ were chosen to be 26° and 82.4° respectively from Ref. 61.

Therefore, $a = \dfrac{\sin 26°}{\tan 82.4°} = 0.0585$

<u>Determination of r_o:</u>

In the following calculations, it is assumed, to a first order approximation, that the function peaks where,

$$\phi = (2n + 1) \frac{\pi}{2}, \; n = 0, \pm 1, \pm 2, \text{ etc.}$$

Let r_o correspond to the radius vector at the commencement of the spiral, i.e., when $\phi = 0$. The low frequency limit is

3.2.3 (continued)

determined by the height of the sine function, and is equivalent to $\lambda/4$ at 75 mc. $\lambda/4$ at 75 mc = 39.3 inches. Therefore, r (at 75 mc) = 39.3 csc 26° = 89.75 inches. Now, the smallest sine peak must be smaller than $\lambda/4$ at 375 mc (7.87 inches). Therefore, r (at 375 mc) = 7.87 inches csc 26° = 17.93 inches.

$$89.75 = r_o e^{a\phi_1}$$

$$17.93 = r_o e^{a\phi_2}$$

$$e^{a(\phi_1-\phi_2)} = \frac{89.75}{17.93} = 5.0$$

$$a(\phi_1-\phi_2) = 1.61$$

$$(\phi_1-\phi_2) = \frac{1.61}{.0585} = 27.5 = 8.76\,\pi$$

Therefore, make $(\phi_1-\phi_2) \geqslant 9\pi$.

In order to have r_o commence with $\phi = 0$, back off $\pi/2$. Therefore, the total angular displacement, from r_o to r = 89.75 inches, is $9\pi + \pi/2 = 19\pi/2$.

$$89.75 = r_o e^{.0585\left(\frac{19\pi}{2}\right)} = r_o e^{1.745}$$

Hence, r_o = 15.66 inches

Therefore, $x = 15.66\, e^{a\phi} \cos 26° = 14.10\, e^{a\phi}$

and $y = 15.66\, e^{a\phi} \sin 26° \sin\phi = 6.87 \sin\phi\, e^{a\phi}$

The computed values of x and y for increments of $\Delta\phi = \pi/4$ are tabulated in Table I.

Utilizing the tabulated data, the VHF model of the Sinuous Log Periodic Antenna was fabricated of bronze screen, which was sewn on a fiberglas insulating screen mounted on a wooden frame. The width of the antenna was chosen as five inches at the low frequency end and gradually tapered toward the high frequency end in inverse proportion to frequency. The active length of the antenna along the axis of the sine function is 77.7 inches. A strip of copper sheet (0.002 inch thick) five inches wide at the low frequency end and tapering in inverse proportion to frequency was soldered along the axis of the sine function. The antenna frame which was constructed in two sections, was hinged to allow the antenna to fold about its axis. The antenna is shown in its fully extended position in Figure 3-18 and folded at right angles in Figure 3-19.

3.2.3 (continued)

determined by the height of the sine function, and is equivalent to $\lambda/4$ at 75 mc. $\lambda/4$ at 75 mc = 39.3 inches. Therefore, r (at 75 mc) = 39.3 csc 26° = 89.75 inches. Now, the smallest sine peak must be smaller than $\lambda/4$ at 375 mc (7.87 inches). Therefore, r (at 375 mc) = 7.87 inches csc 26° = 17.93 inches.

$$89.75 = r_o e^{a\phi_1}$$

$$17.93 = r_o e^{a\phi_2}$$

$$e^{a(\phi_1-\phi_2)} = \frac{89.75}{17.93} = 5.0$$

$$a(\phi_1-\phi_2) = 1.61$$

$$(\phi_1-\phi_2) = \frac{1.61}{.0585} = 27.5 = 8.76\,\pi$$

Therefore, make $(\phi_1-\phi_2) \geqslant 9\pi$.

In order to have r_o commence with $\phi = 0$, back off $\pi/2$. Therefore, the total angular displacement, from r_o to r = 89.75 inches, is $9\pi + \pi/2 = 19\pi/2$.

$$89.75 = r_o e^{.0585\left(\frac{19\pi}{2}\right)} = r_o e^{1.745}$$

Hence, $r_o = 15.66$ inches

Therefore, $x = 15.66\, e^{a\phi} \cos 26° = 14.10\, e^{a\phi}$

and $y = 15.66\, e^{a\phi} \sin 26° \sin\phi = 6.87 \sin\phi\, e^{a\phi}$

The computed values of x and y for increments of $\Delta\phi = \pi/4$ are tabulated in Table I.

Utilizing the tabulated data, the VHF model of the Sinuous Log Periodic Antenna was fabricated of bronze screen, which was sewn on a fiberglas insulating screen mounted on a wooden frame. The width of the antenna was chosen as five inches at the low frequency end and gradually tapered toward the high frequency end in inverse proportion to frequency. The active length of the antenna along the axis of the sine function is 77.7 inches. A strip of copper sheet (0.002 inch thick) five inches wide at the low frequency end and tapering in inverse proportion to frequency was soldered along the axis of the sine function. The antenna frame which was constructed in two sections, was hinged to allow the antenna to fold about its axis. The antenna is shown in its fully extended position in Figure 3-18 and folded at right angles in Figure 3-19.

TABLE I

COMPUTATION OF THE X AND Y COORDINATES IN INCREMENTS OF $\Delta\phi = \pi/4$

ϕ	$a\phi$	$e^{a\phi}$	$\sin\phi$	$e^{a\phi}\sin\phi$	$x = 14.10\ e^{a\phi}$	$y = 6.87 \sin\phi e^{a\phi}$
0	0.00	1.000	0.000	0.000	14.10	0.00
$\pi/4$	0.046	1.047	0.707	0.740	14.75	5.08
$\pi/2$	0.092	1.096	1.000	1.096	15.45	7.52
$3\pi/4$	0.138	1.148	0.707	0.811	16.18	5.56
π	0.184	1.202	0.000	0.000	16.97	0.00
$5\pi/4$	0.230	1.258	-0.707	-0.890	17.75	-6.10
$3\pi/2$	0.276	1.318	-1.000	-1.318	18.60	-9.04
$7\pi/4$	0.322	1.380	-0.707	-0.975	19.46	-6.69
2π	0.368	1.445	0.000	0.000	20.40	0.00
$9\pi/4$	0.414	1.512	0.707	1.070	21.30	7.34
$5\pi/2$	0.460	1.584	1.000	1.584	22.30	10.87
$11\pi/4$	0.506	1.658	0.707	1.172	23.36	8.04
3π	0.552	1.737	0.000	0.000	24.50	0.00
$13\pi/4$	0.598	1.818	-0.707	-1.285	25.6	-8.82
$7\pi/2$	0.644	1.903	-1.000	-1.903	26.9	-13.06
$15\pi/4$	0.690	1.993	-0.707	-1.410	28.1	-9.68
4π	0.736	2.088	0.000	0.000	29.5	0.00
$17\pi/4$	0.782	2.186	0.707	1.546	30.9	10.60
$9\pi/2$	0.828	2.290	1.000	2.290	32.3	15.72
$19\pi/4$	0.874	2.397	0.707	1.693	33.8	11.62
5π	0.920	2.508	0.000	0.000	35.4	0.00
$21\pi/4$	0.967	2.628	-0.707	-1.860	37.0	-12.75
$11\pi/2$	1.011	2.750	-1.000	-2.750	38.8	-18.89
$23\pi/4$	1.057	2.876	-0.707	-2.033	40.5	-13.94
6π	1.103	3.015	0.000	0.000	42.5	0.00
$25\pi/4$	1.15	3.160	0.707	2.235	44.6	15.33
$13\pi/2$	1.196	3.305	1.000	3.305	46.6	22.70
$27\pi/4$	1.242	3.470	0.707	2.454	48.9	16.85
7π	1.287	3.620	0.000	0.000	51.0	0.00
$29\pi/4$	1.333	3.790	-0.707	-2.680	53.4	-18.40
$15\pi/2$	1.380	3.975	-1.000	-3.975	56.0	-27.30
$31\pi/4$	1.425	4.15	-0.707	-2.94	58.5	-20.2
8π	1.472	4.35	0.000	0.00	61.3	0.00
$33\pi/4$	1.519	4.56	0.707	3.22	64.2	22.1
$17\pi/2$	1.565	4.79	1.000	4.79	67.5	32.9
$35\pi/4$	1.610	5.00	0.707	3.54	70.5	24.3
9π	1.655	5.24	0.000	0.00	73.8	0.00
$37\pi/4$	1.701	5.48	-0.707	-3.87	77.3	-26.6
$19\pi/2$	1.745	5.73	-1.000	-5.73	80.8	-39.3
$39\pi/4$	1.795	6.01	-0.707	-4.25	84.8	-29.2
10π	1.840	6.30	0.000	0.00	88.8	0.00

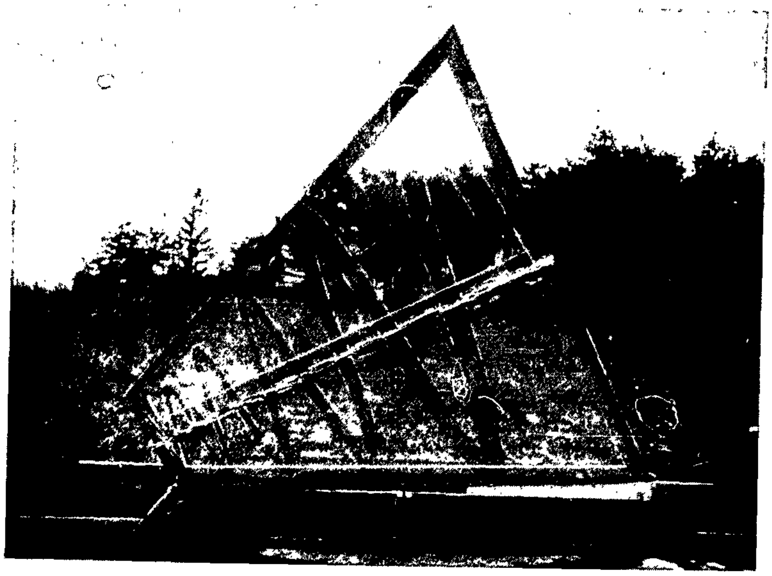

Figure 3-18: VHF Model of Sinuous Log Periodic Antenna Fully Extended

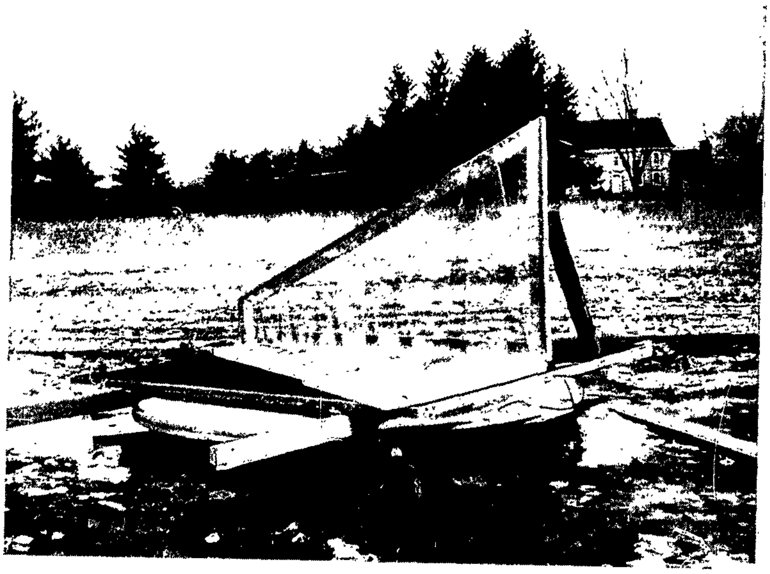

Figure 3-19: VHF Model of Sinuous Log Periodic Antenna Folded at Right Angles

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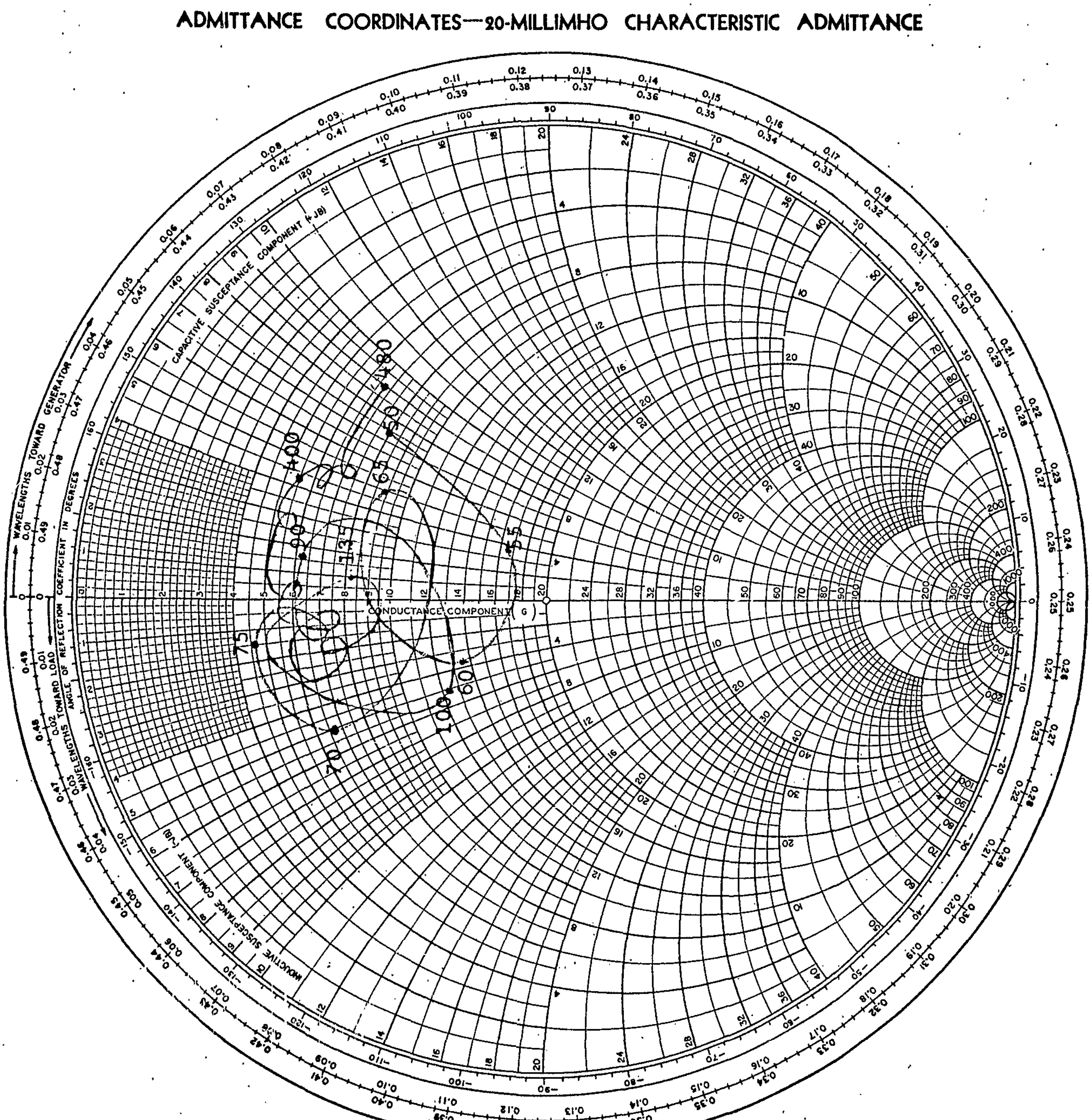

Figure 3-20: Input Admittance of VHF Model of Sinuous Log Periodic Antenna Operated in the Fully Extended Position (f = 50-480 mc).

3.2.4 VHF Model Evaluation

Input admittance and radiation pattern measurements were taken of the VHF model of the Sinuous Log Periodic Antenna in both the "fully extended" and "folded at right angles" configurations. In each case the antenna was mounted approximately two inches above an 8 x 8 foot ground plane. Smith chart representation of the admittance variations over the frequency range 50-480 mc are shown for the "fully extended" and "folded at right angles" configurations in Figure 3-20 and Figure 3-21 respectively. Figure 3-22 and 3-23 show radiation patterns for the fully extended operation over the frequency range 50-425 mc, and Figures 3-24 and 3-25 show patterns for the folded operation over the range 50-480 mc.

Although a comparison of the input admittance plots indicate a slight deterioration of the low frequency performance of the folded from the fully extended operation, the radiation patterns show that both configurations operate almost equally well.

In view of the above, it can be seen that of the two configurations, the folded one is preferable, since substantial height reduction (2:1) is effected by means of the folding operation.

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ADMITTANCE COORDINATES—20-MILLIMHO CHARACTERISTIC ADMITTANCE

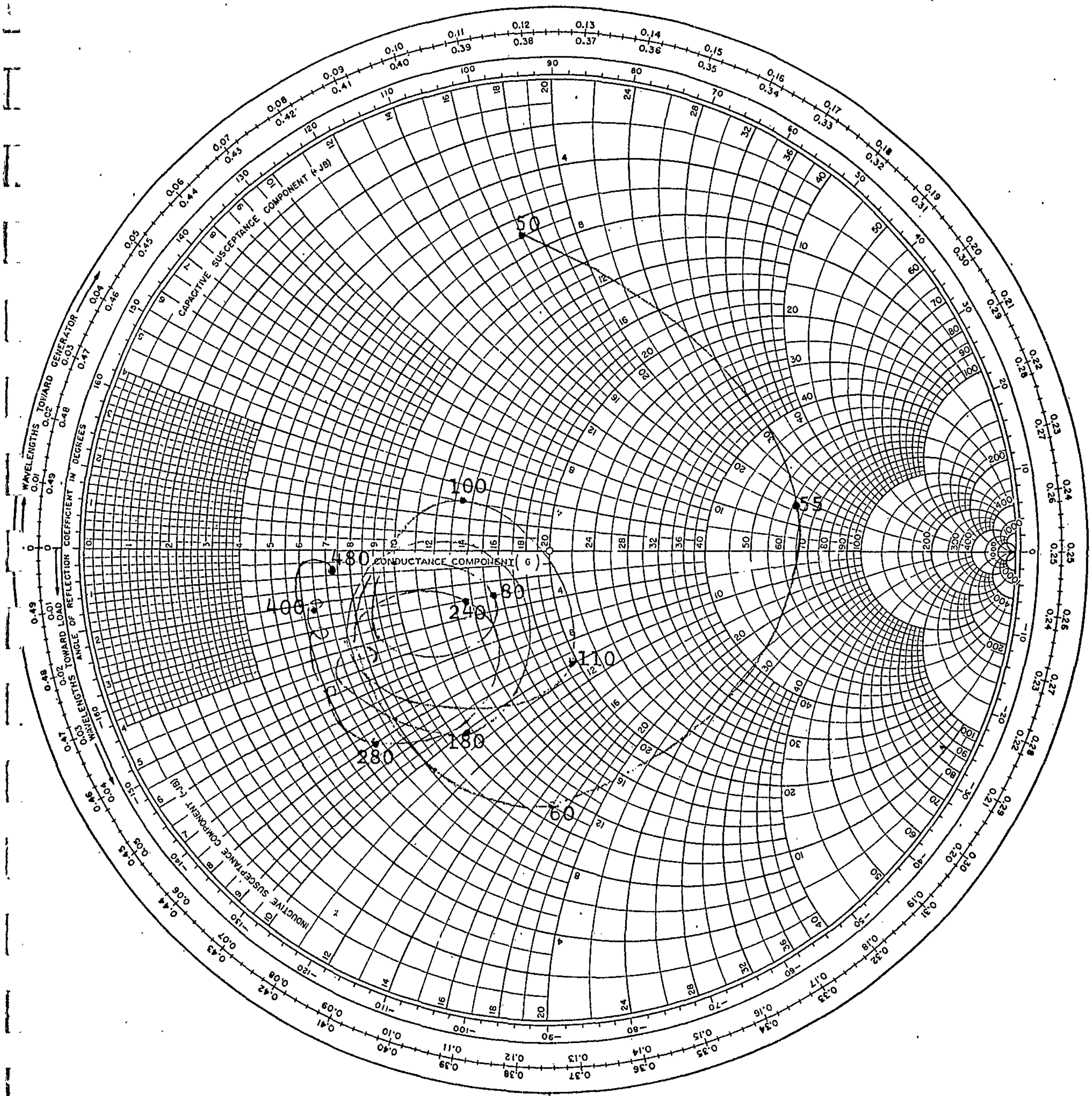
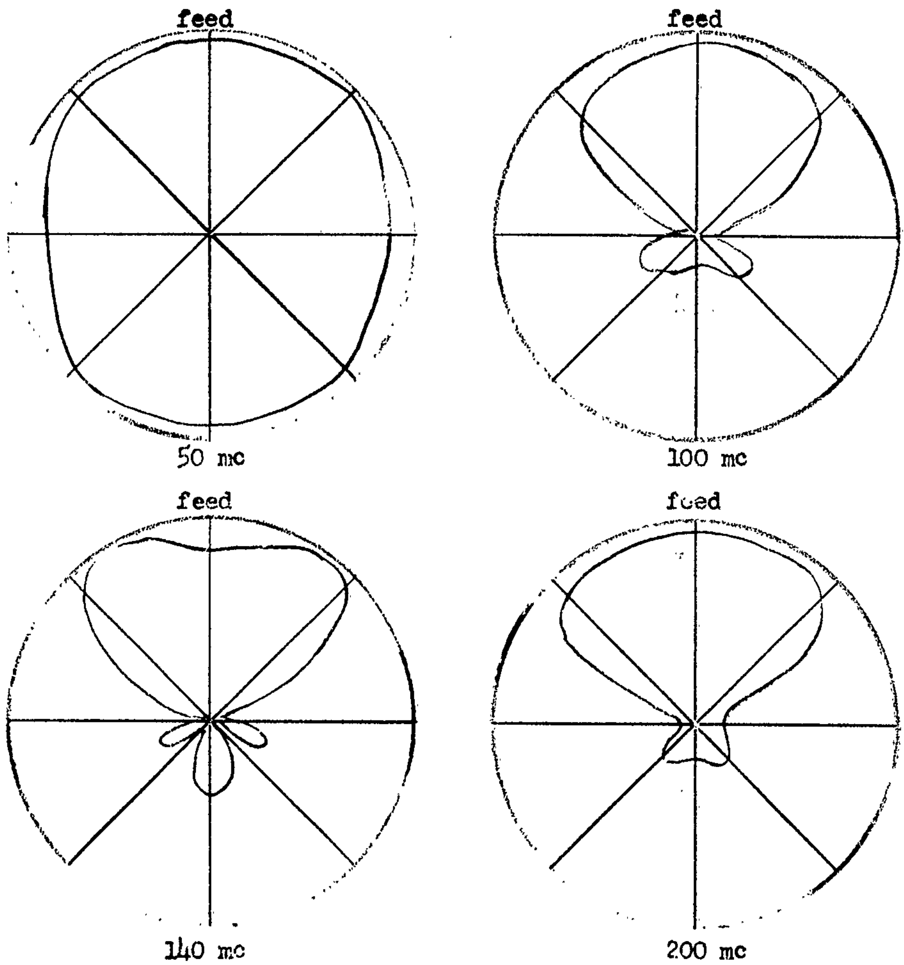
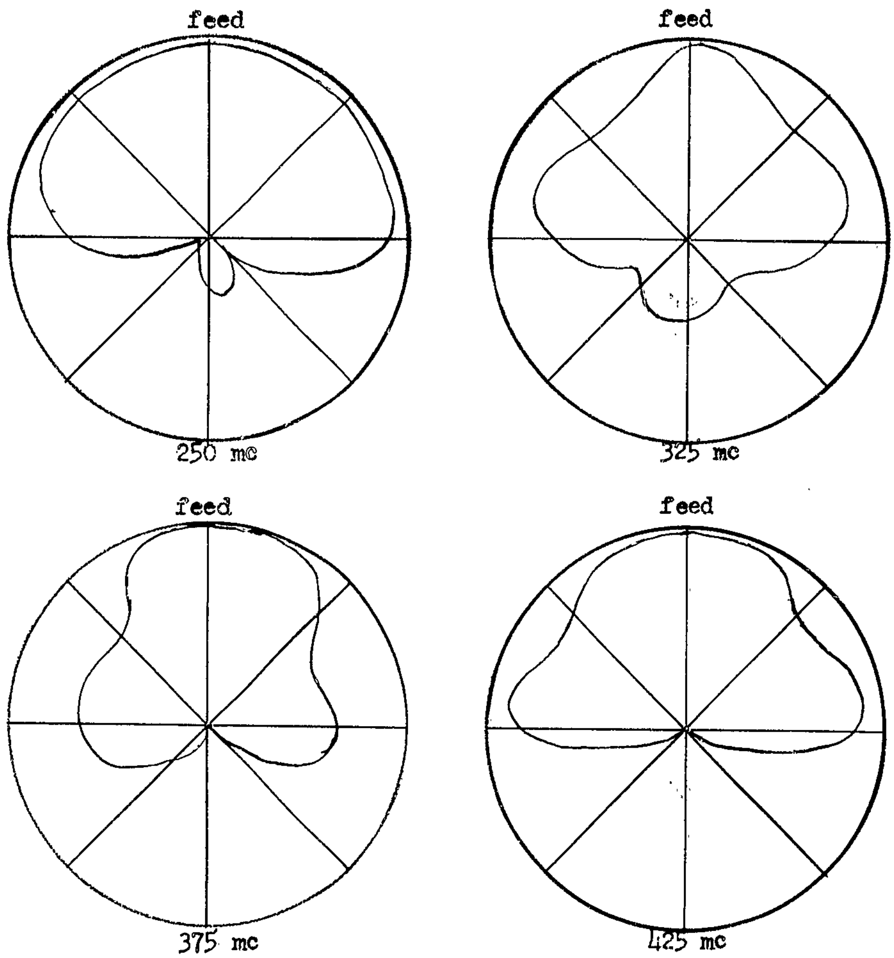


Figure 3-21: Input Admittance of VHF Model of Sinuous Log Periodic Antenna Folded at Right Angles. (f = 50-480 mc)



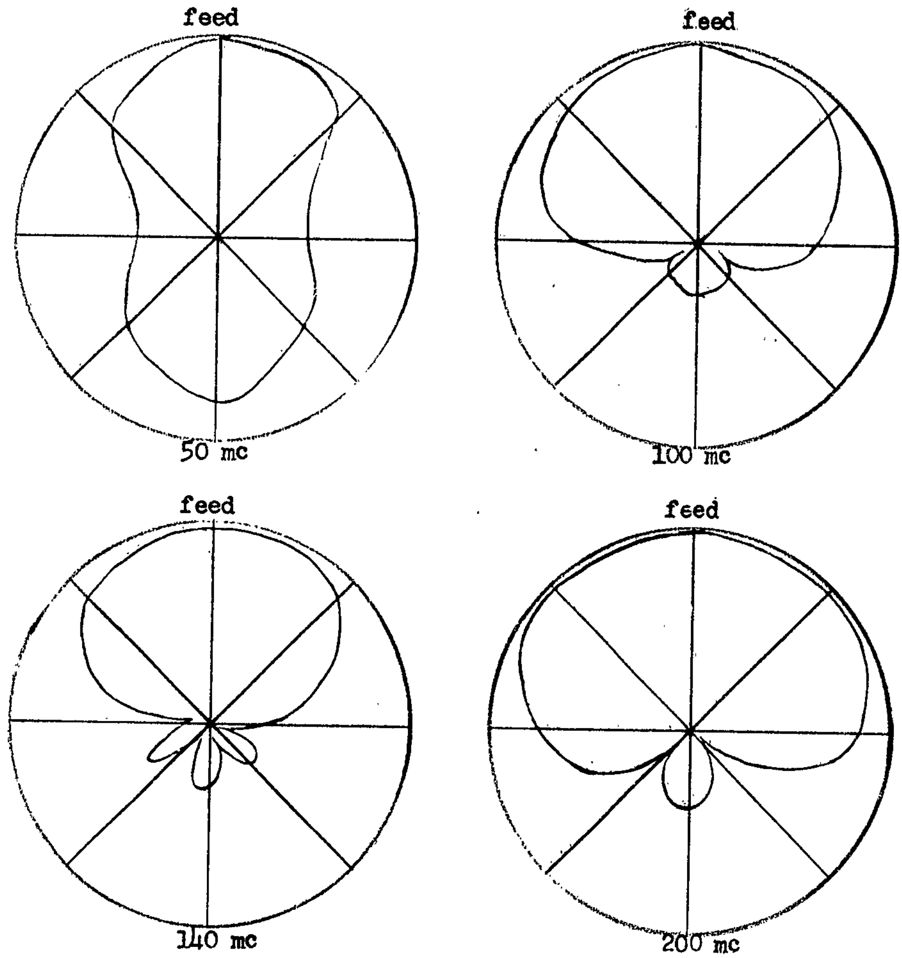
Scale = normalized voltage: 0 to 1.0

Figure 3-22: Measured Radiation Pattern of the Sinuous Log Periodic Antenna Fully Extended. Vertical Polarization.



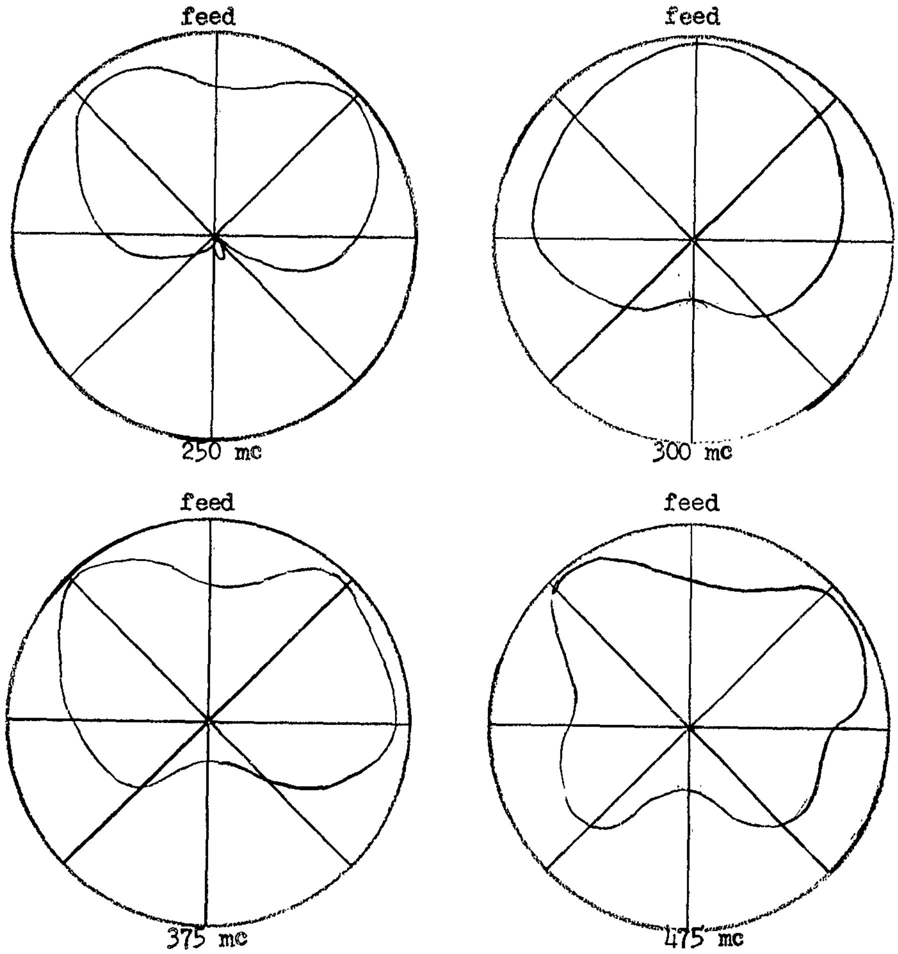
Scale = normalized voltage: 0 to 1.0

Figure 3-23: Measured Radiation Pattern of the Sinuous Log Periodic Antenna Fully Extended. Vertical Polarization.



Scale = normalized voltage: 0 to 1.0

Figure 3-24: Measured Radiation Pattern of Sinuous Log Antenna Folded 90°. Vertical Polarization.



Scale = normalized voltage: 0 to 1.0

Figure 3-25: Measured Radiation Pattern of Sinuous Log Antenna Folded 90°. Vertical Polarization

4.0 PROPOSED MECHANICAL CONSTRUCTION OF FULL SIZE ENGINEERING MODEL SCIMITAR BROADBAND ANTENNA

The proposed full-size engineering model of a Scimitar Broadband Antenna will have the radiating area contained in an outline 27.5 feet high and 49 feet wide. The model will be built for operational use. Thus it can be packed into a volume of 12 cubic feet and have a weight of approximately 111 pounds. It is estimated that the model can be erected in two hours by a three-man crew.

The following is a description of the antenna construction and a discussion of the materials chosen for the model. This model is designed to operate at any frequency in the 6 to 30 mc range.

4.1 Description

4.1.1 Layout

The proposed engineering model will be designed to incorporate, to the largest extent possible, the features desired in the final product. Thus, the design goals will be minimum weight, minimum wind resistance, maximum durability and ease of erection, as well as compliance with all electrical requirements.

The antenna array will consist of a suitable pattern of tinned copper braid sewn to a carrier mesh. The carrier will be held aloft by a support system consisting of a multi-section center pole and suitable guys.

An illustration of the proposed design is given in Figure 4-1. The minimum height of the center pole is 34 feet 5 inches. For actual practice, it will most likely consist of seven sections of 5 feet 0 inches length and will be 35 feet high. It will be hinged to a suitable base fabricated of aluminum. Hinging is common practice for such masts to facilitate erection. The base will be capable of being staked to the ground. Up to a height of 25 feet the pole will consist of aluminum tubing; the balance will be fiberglas so as not to interfere with the radiation pattern.

The carrier mesh will be an irregular pentagon defined by points A, B, C, D and E in Figure 1. It will be suspended from the main guys FC and GC and restrained in its own plane by the vertical guys AB and ED, and by lashings to the center pole. Also, the carrier base line will be staked to the ground along the line AE.

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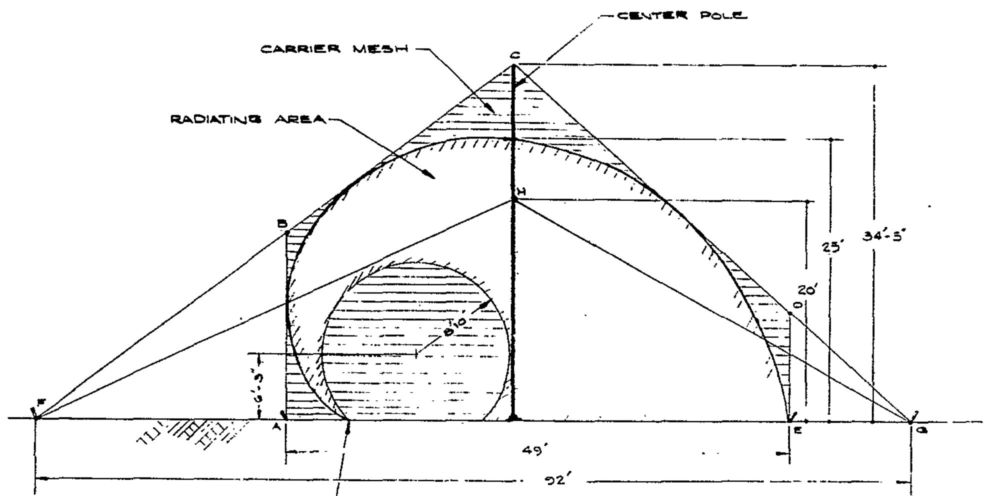

FIGURE 4-1
ELEVATION OF ANTENNA

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GENERAL PRECISION, INC AEROSPACE GROUP LITTLE FALLS, NEW JERSEY Kearfott DIVISION	ELEVATION OF ANTENNA	TECHNICAL PROPOSAL NO.____ FIGURE NO.____
	DR L DeVincentis 3/22/63 APPD	DWG NO. C200604296 REV 1

4.1.1 (continued)

Additional guys will be provided to steady the center pole. In the plane of the antenna, these guys will run from A to H and from E to H. Two corresponding guys will be run from point H in a plane perpendicular to the antenna, and two more guys from point C.

The ground terminations of the guys will be suitable stakes, and turnbuckles will be provided as needed.

A suitable ground plane will be provided consisting of metallized netting. This area will be subdivided into two halves so that it can be emplaced after erection of the antenna proper. The ground plane will be staked in place to prevent flutter or billowing.

4.1.2 Selection of Materials

All materials will be chosen for ruggedness to withstand the expected environmental and handling conditions, and for minimum weight compatible with performance.

The materials enumerated below were chosen after a preliminary survey. Therefore, the selections are still tentative, and if materials having better over-all performance come to Kearfott's attention, we will use them.

The carrier mesh will be made of nylon tire cord treated to increase service life in air and sunlight, and also to eliminate stretch. The cord will be about 0.050 inch thick, and will be woven into a diamond pattern with about 1.00 to 2.00 inches leg length. The yield of this material is about 47 and 100 square feet of mesh material per pound weight respectively.

The guys and ropes will be dacron cordage. This material is lightweight, resistant to sunlight, humidity, chafing and rough handling, and requires practically no maintenance. Its presence does not affect the radiation pattern of the antenna.

The radiating area of the antenna will be made up of intersecting lines of tinned copper braid, fastened to the carrier mesh. This braid is an excellent conductor and is protected from atmospheric attack by the tin coating. It is easily soldered, so that good electrical contact can be made at ease where lines of braid crosss one another and at the feed point.

4.1.2 (continued)

The braid is very flexible, a very important consideration in this equipment, which must be stowable in a minimum of space. The carrier mesh with the antenna pattern secured to it is folded several times as required for insertion into the shipping container. It is expected that the combination of mesh and braid can be handled in this manner as often as required and without difficulty.

The braid chosen tentatively has a nominal flat width of 0.094 inch and a thickness of 0.020 inch. It corresponds to a wire of No. 19 AWG and has a nominal current carrying capacity of 11 amperes. The next smaller braid size will also be investigated.

The center pole will consist of five sections of aluminum tubing and two sections of fiberglas tubing, each section five feet long and having an approximate diameter of two inches.

The individual pole sections will be interconnected by insertion of a male end into a socket, as shown in Figure 4-2. Thrust will be transmitted from one section to the next by means of collars. Once sections are connected, they are secured by lockable steel crosspins. These pins will be of the ball lock pin-type widely used in the aircraft industry. Pins are held to their corresponding pole sections by chains.

Essentially, the design of the center pole, base and rigging will be similar to that used in the Signal Corps Antenna AS 19 (*) TRC 1 and AS 20 TRC 1. These antennas have 40 to 50 foot sectional masts which are considered to have been proven in actual service.

At present, it is expected that the ground plane will consist of metallized cloth. One fabric which seems suitable, and which is said to have been used successfully in inflatable antennas, is a heavy nylon marquisette metallized with silver. This material is manufactured by the Swift Textile Metallizing and Laminating Corporation of Hartford, Connecticut. This fabric is said to withstand repeated rolling and folding without deterioration of conductivity. One very attractive property is its light weight, 3-3/4 ounches per square yard. This light weight will require proper staking in the field.

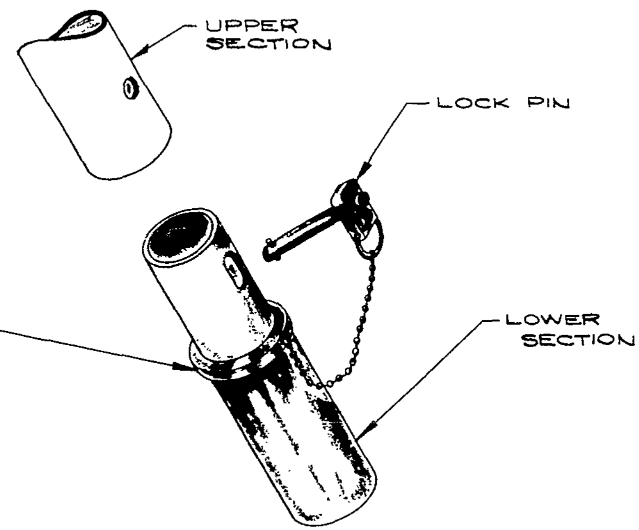

FIGURE 4-2
CONNECTION OF CENTER POLE SECTION

KEARFOTT DIVISION GENERAL PRECISION, INC. LITTLE FALLS, NEW JERSEY	CONNECTION OF CENTER POLE SECTION	TECHNICAL PROPOSAL NO. ___ FIGURE NO. ___
	DR L DeVINCENTIS 3-22-63 APPD 4-1-63	DWG NO. C200604299 REV 1

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4.1.2 (continued)

The resistance of this material is given as 2 to 5 ohms per square, which will probably rule it out for the radiating surface of the antenna proper. However, the radiating properties will also be investigated.

4.2 Erection and Disassembly (See Figure 4-3)

The antenna is designed for fast erection by a crew of no more than three men.

Tentatively, the following step-by-step procedure will be followed:

1. A suitable open area will be chosen.
2. The center pole will be assembled.
3. The lower end of the center pole will be inserted into the socket of the base, and the base will be staked to the ground.
4. The guy stakes will be laid out and driven into the ground.
5. The rigging for the antenna will now be laid out on the ground and the guys from points C and H located behind the antenna will be fastened to their stakes.
6. The antenna carrier mesh will be unrolled, laid out and fastened to the rigging with suitable rings. The input cable will be connected to the feed point.
7. The antenna will then be erected by tensioning the two front guys from points C and H as shown in Figure 4-3. It is not believed that a gin pole will have to be used for erection.
8. After erection, all guys will be tensioned.
9. Finally, the ground plane will be laid out and staked down.

Disassembly will follow the above procedure in reverse.

It is estimated that assembly can be completed by three men in about two hours. This time could be reduced to about one hour by additional man power.

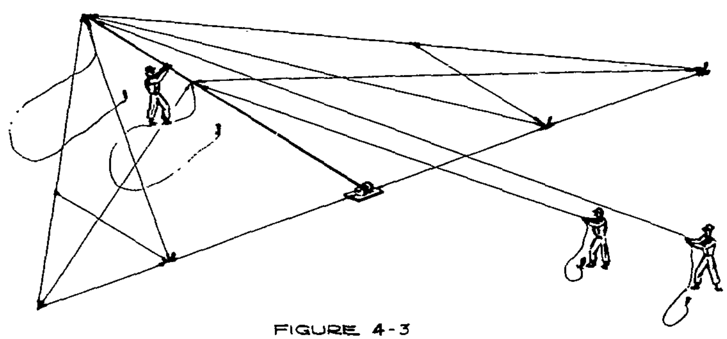

FIGURE 4-3
ERECTION PROCEDURE

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GENERAL PRECISION, INC AEROSPACE GROUP LITTLE FALLS, NEW JERSEY Kearfott DIVISION	ERECTION PROCEDURE	TECHNICAL PROPOSAL NO.____ FIGURE NO.____
	DR L.DEVINCENTIS 32243 APPD [illegible] 4-1-63	DWG NO. C200604298 REV 1

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4.3 Packaging Breakdown

Based on preliminary estimates and data received from manufacturers, the equipment will be broken down into three loads as follows:

Carrier mesh with antenna and associated ropes and guys	38 pounds
Pole and ground plane	35 pounds
Guys, stakes, pole base and tools	38 pounds
	111 pounds

Total estimated volume of disassembled antenna, complete with tools, is 12 cubic feet.

5.0 CONCLUSIONS

The Scimitar Antenna is selected as the approach offering the optimum in size reduction and ease of installation for immediate prototype development. A preliminary mechanical design and installation method have been evolved (see Section 4).

Both the Sinuous Log Periodic and the Conical Spiral Antennas were technically successful; however, they were not quite as small or simple to erect, as the Scimitar type.

The state-of-the-art survey confirmed the selection of the Log Periodic Monopole as the best subject for scale model development and evaluation. Little is presently being done in the field toward size reduction of broadband antennas. Such developments as the DDRR antenna are extremely narrow band and have a mechanically restricted tuning range. The Granger antenna is horizontally polarized and has local coverage gaps, rendering it unsuited to the application. More intensive research and closer contacts with development agencies is recommended.

Kearfott believes it has demonstrated appropriate energy and ingenuity in a pragmatic approach to the Marine Corps problems. A thorough survey shows that very little is being done at any other facility. In view of our extensive experience and meaningful results, we feel particularly well qualified to continue the study program.

APPENDIX

BIBLIOGRAPHY

APPENDIX

BIBLIOGRAPHY

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